BBC

25 WINTER TARGETS FOR URBAN OBSERVERS

#212 JANUARY 2023

Sky at Night

THE UK'S BEST-SELLING ASTRONOMY MAGAZINE

STARGAZING IN 2023

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PLUS Space mission launches

NEW YEAR NEW COMET

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VAONIS VESPERA OBSERVATION STATION ON TEST

UK'S LAUNCH FACILITIES GET READY FOR LIFT-OFF

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Welcome

There's nothing like stargazing on dark, crisp winter nights

The New Year is a perfect time for wrapping up warm, getting out and looking up. There's an abundance of starry sights to track down – but where to start? Help is at hand as we look ahead to the targets you mustn't miss, both this winter and further ahead. Turn to Ezzy Pearson's feature on **page 29** to see why 2023 could be the year of meteor showers, and to hear about the major space missions due to launch this year.

Winter's long nights, when darkness falls early, are also ideal for introducing your family to the night sky, especially younger kids who won't need to stay up too late. On **page 34**, astronomy educator Mary McIntyre shares her advice on how to get first-time stargazers, young or old, using telescopes and binoculars, and getting to know the constellations.

And our exploration of the night sky continues in the final part of veteran US astronomer Rod Mollise's series on observing from urban and suburban locations. Turn to **page 66** for his tips on 25 winter deep-sky objects that all fare well against light pollution.

As one series ends, another starts as we kick off our Cosmology Crash Course. Over the coming months, astronomy author Govert Schilling will explain some of the most fundamental questions when it comes to understanding the Universe, starting with: why it is that light from galaxies in the early Universe appears to us now as red? Turn to **page 40** to find out the answer!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 19 January 2023.

HOW TO CONTACT US

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

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Visit our website for competitions, astrophoto galleries, observing guides and more

Social media
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Podcasts
Listen to our Radio Astronomy podcasts where the magazine team and guests discuss astro news

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The Sky Guide

16-PAGE CENTRE PULLOUT

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Mary McIntyre

Outreach astronomer

"Astronomy is a great way of bringing the family together, with a range of different stargazing activities for all ages and abilities". **Mary shares her tips for family-friendly astronomy everyone will enjoy,** page 34

Rod Mollise

Astronomy author

"I hope my series has given city stargazers hope that there are galaxies, star clusters and even nebulae they can go for." **In the final part of his series, Rod reveals the best winter deep-sky targets from urban skies,** page 66

Anita Chandran

Science writer

"Isaac Newton was a pivotal figure in astronomy, but also a complicated and isolated man. On his 380th birthday, I had the chance to look back at the work that made him a household name." **Find out more on** page 72

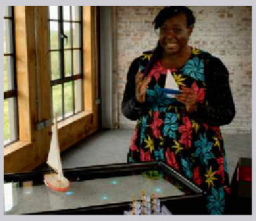
Extra content ONLINE

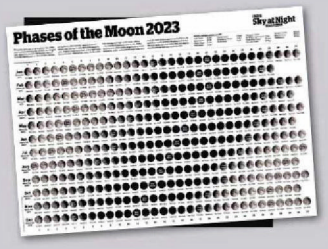
Visit **www.skyatnightmagazine.com/bonus-content/6UIJHY6** to access this month's selection of exclusive Bonus Content

JANUARY HIGHLIGHTS

Interview: Making alien contact

Exoplanet researcher Emma Johanna Puranen on what would happen if we found extraterrestrial intelligence.





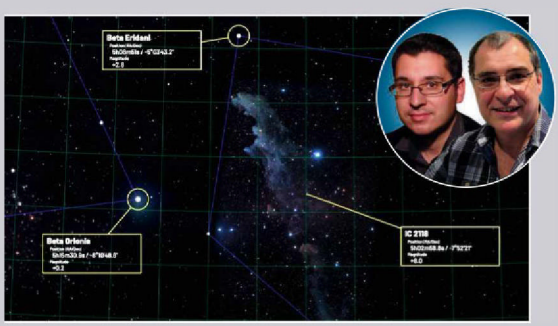
***The Sky at Night:* Multiverse of Mystery**

The team explore science fiction ideas like multi-verses and interstellar travel, asking if they could ever become science fact.

Download your 2023 Moon phases poster

Access the lunar phase dates and times for the whole of the coming year, delivered directly to your smartphone or tablet.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

STAR SPECK: THE NEXT GENERATION

A tiny protostar shines at the heart of the huge cloud that's feeding it

JAMES WEBB SPACE TELESCOPE, 16 NOVEMBER 2022

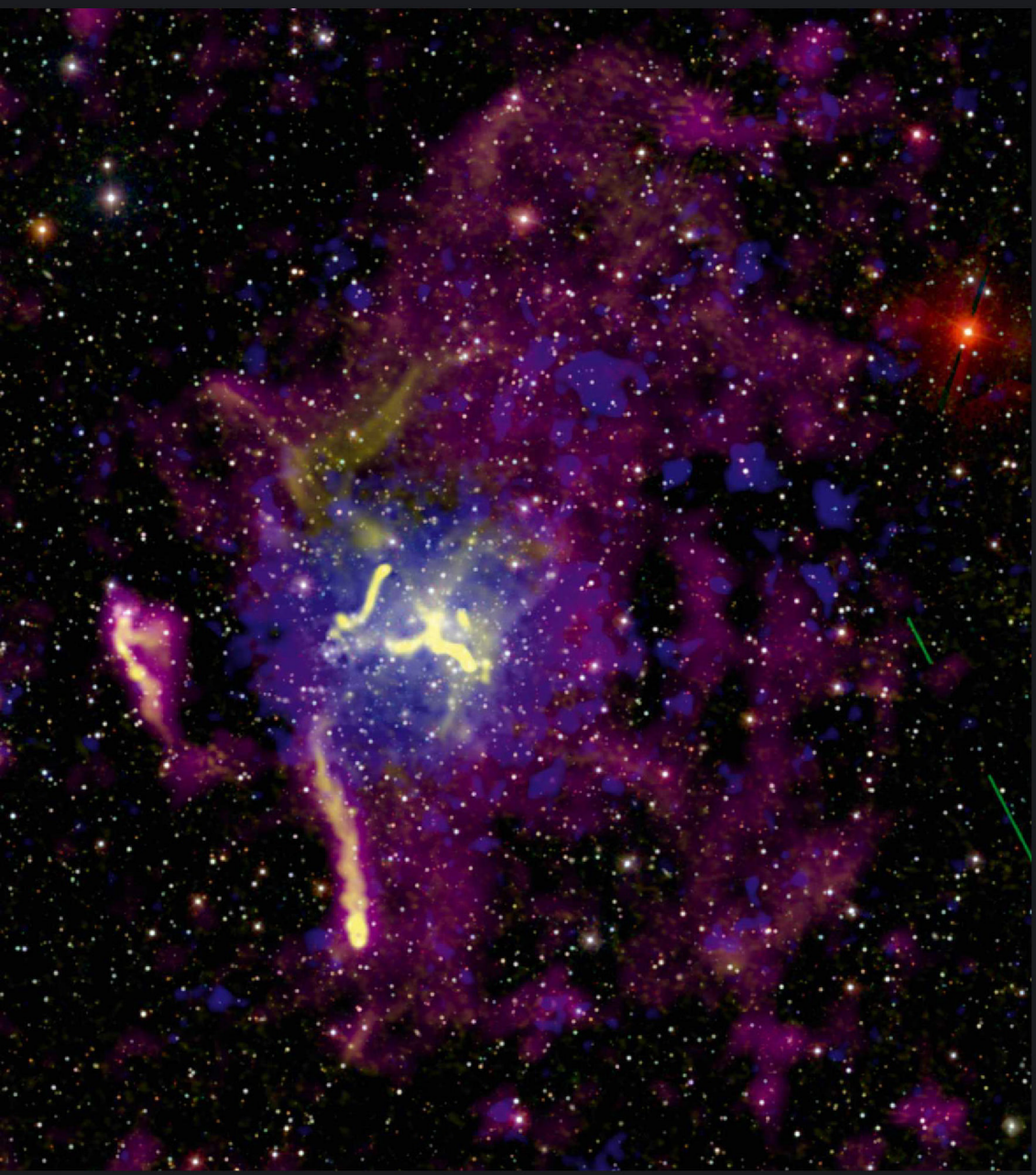
This extraordinary image shows a new star in the process of growing up. Taken by the NIRCam instrument on board the JWST, the protostar, a tiny speck at the centre of the cloud, is drawing new substance from the molecular cloud that surrounds it.

There's more to the image than the spectacular hourglass shape, however. Ejections from the star – L1527 in Taurus – have cleared out cavities above and below it whose boundaries glow orange and blue in this infrared view. In fact, the star-forming region is only visible in infrared, as the colours are created by layers of dust between the star and telescope, with the blue areas being where the dust is thinnest.

The cloud is shaped by shocks and turbulence from L1527, which inhibit the formation of other stars in the cloud, meaning this infant sun, only around 100,000 years old, has plenty to sate its appetite.

MORE **ONLINE**
Explore a gallery of these and more stunning space images

NASA/ESA/CSA AND STSCI. IMAGE PROCESSING: J. DEPASQUALE/A. PAGAN AND A. KOEKEMOER (STSCI)



△ Meet the neighbours

ORION SPACE CAPSULE, ARTEMIS I MISSION, 16 AND 21 NOVEMBER 2022

A GoPro camera placed on the tip of one of the Orion capsule's solar arrays provides a view of Earth looking very alone in the Universe, with the capsule body and solar panel looming in the foreground, as the Artemis I mission leaves Earth's orbit bound for the Moon. Later, the capsule used its navigation camera to snap the rarely-seen far side, the giant Tsiolkovskiy impact crater clearly visible.

◁ Long-distance relationships

ROSAT/LOFAR/SDSS, 2 NOVEMBER 2022

This is Abell 2255, a cluster of thousands of galaxies about a billion lightyears away. The image combines X-ray data from the defunct German-led ROSAT space telescope (blue) with radio emissions gathered by the Low-Frequency Array (yellow and purple) and a background image from the Sloan Digital Sky Survey. It shows an area of 324 million square lightyears, which from Earth covers a region of the sky the size of four full Moons.

△ Let's twist again

JUNO, 6 NOVEMBER 2022

From a distance of about 19,000km above Jupiter's north pole, Juno captured this image of circumpolar vortices, which was processed by citizen scientist Andrea Luck. The vortices, discovered by Juno in 2016, are still a mystery. There are nine at the north pole and six at the south, in what appear to be stable patterns, but scientists still aren't sure what keeps them that way, and why they behave differently to similar storms on Saturn.

▽ Ancient galaxies revealed

JAMES WEBB SPACE TELESCOPE, 17 NOVEMBER 2022

Here, Webb is peering through a giant galaxy cluster, Abell 2744. While that is spectacular enough, the highlighted galaxies are two of the oldest and most distant ever captured. The galaxy highlighted on the left existed only 450 million years after the Big Bang; the one on the right, just 350 million years after the Big Bang. Tiny by galactic standards, these ancient galaxies are only a few per cent of the size of the Milky Way.

NASA, ROSAT/LOFAR/SDSS/BOTTEON ET AL, NASA/JPL-CALTECH/SWRI/MSSS/ANDREALUCK, NASA/ESA/CSA/TOMMASO TREU (UCLA) PROCESSING BY ZOLT G. LEVAY (STSCI)

The latest astronomy and space news, written by Ezzy Pearson

BULLETIN

Artemis, Moon and Earth: Orion has now travelled further than any other human-rated spacecraft

NASA/BILL INGALLS; NASA/KEEGAN BARBER X 2

Artemis I launches and circles the Moon

Countdown begins on returning humans to the lunar surface by the decade's end

NASA has finally taken a small step towards putting the first woman and person of colour on the Moon, after its Artemis I mission successfully launched and arrived in lunar orbit.

"What an incredible sight to see NASA's Space Launch System rocket and Orion spacecraft launch together for the first time," says NASA administrator Bill Nelson. "This uncrewed flight test will push Orion to the limits in the rigours of deep space, helping us prepare for human exploration on the Moon and, ultimately, Mars."

The flight is the maiden voyage of the rocket and crew module that will eventually return humans to the Moon. But the $4 billion project has been beset by delays, twice returning to the Vehicle Assembly Building to repair leaking fuel lines and shelter from Hurricane Ian. On 15 November it looked like all was on track, when another fuel leak was discovered, requiring the dispatch of a Red Crew, a team of technicians trained to work in the dangerous area beneath a fully fuelled rocket.

"We were very focused on what was happening up there," said Trent Annis, a member of the Red Crew along with Chad Garrett and Billy Cairns. "The rocket – it's alive, it's creaking, it's making venting noises. My heart was pumping. But as soon as we got up those stairs, we were ready to rock and roll."

After the team successfully completed the repair, the countdown recommenced and Artemis I launched at 01:47 EST (06:47 GMT) on 16 November. Thousands watched the launch from the Florida coast, cheering as the rocket's flaming tail lit up the night.

The upper stage reached orbit within eight minutes and departed Earth 90 minutes later. It arrived at the Moon on 21 November, passing just 130km from the surface. It entered into a distant retrograde orbit 64,000km above the surface on 25 November. On 28 November, the Moon was at its furthest distance from Earth, meaning Artemis I was 432,210km away, beating Apollo 13's record for the furthest a human-rated spacecraft has ventured away from our home planet.

At the time of writing, the spacecraft was still at the Moon and will return to Earth and splashdown in the Pacific Ocean on 11 December.

www.nasa.gov

History repeats itself: 50 years on from Apollo, the US reignites its Moon-landing dreams

Comment

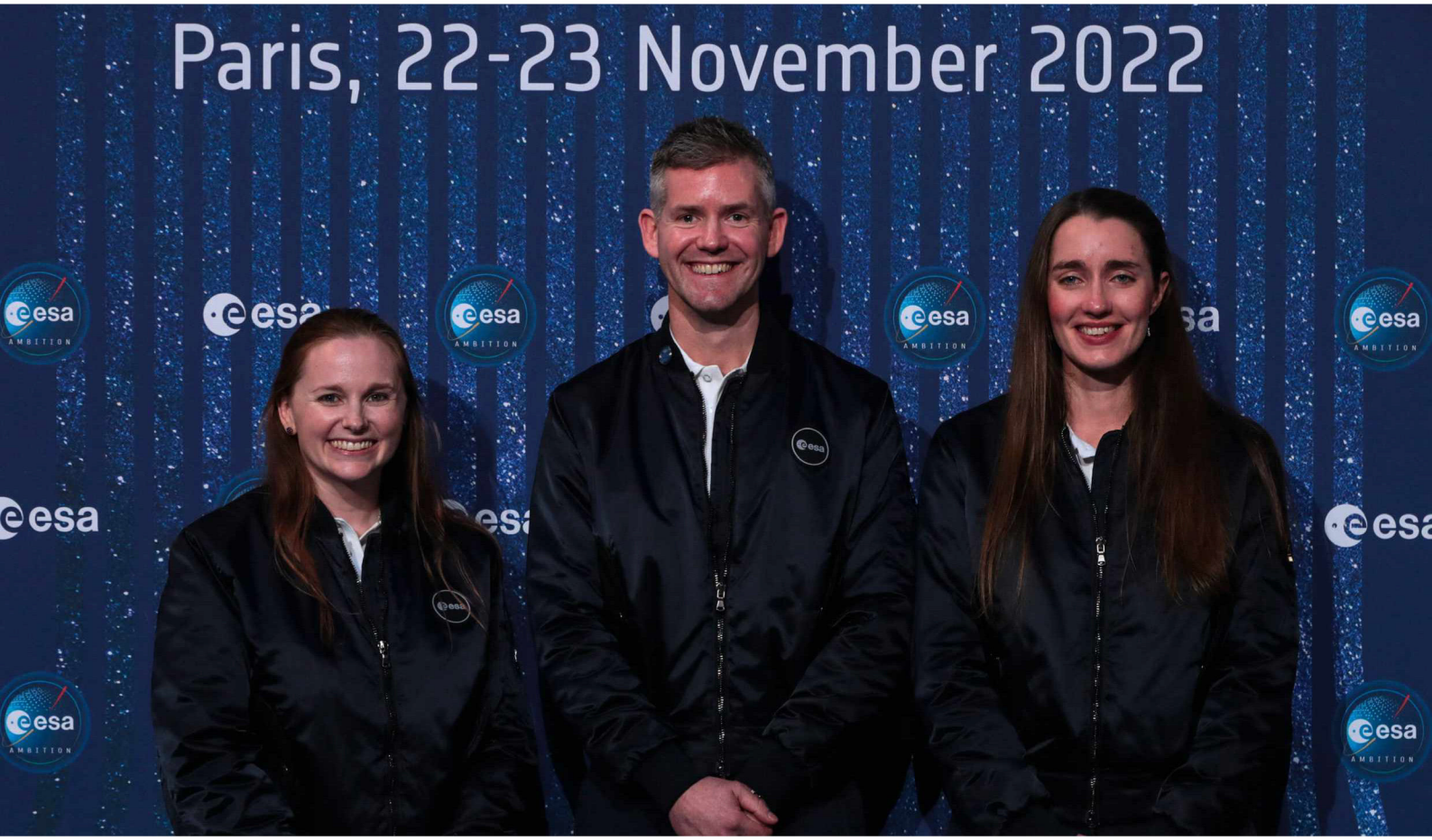
I'm inspired and excited by the success (so far!) of the Artemis I mission. Even watching online, the launch of the giant SLS booster was spectacular, lighting up the Florida night with a brilliance unmatched since the days of the mighty Saturn V. The shots sent back from the Orion capsule, particularly those showing the unfamiliar lunar far side (see **page 8**), with Earth impossibly distant in the same frame, are iconic.

It's not just a NASA mission; contributions from our own European Space Agency include the service module and solar panels for Orion, as well as the presence on board of Shaun the Sheep, nattily dressed in an ESA flight suit.

Artemis is undoubtedly expensive, and the programme's future is still uncertain. But right now, with international cooperation up front, it is serving as a reminder that space is something we can all explore together, and not just a playground for rich men playing with rockets.

Chris Lintott co-presents *The Sky at Night*

▸ Third time lucky: the last-minute glitch fixed, ecstatic crowds watch the launch



▲ ESA's new astronaut intake includes British citizens (left to right) Meganne Christian, John McFall and Rosemary Coogan

Three UK astronauts announced by ESA

The 17 candidates are the agency's first new astronaut class since Tim Peake's in 2008

The UK has three new potential astronauts – including the first-ever astronaut with a disability – after the European Space Agency announced its new class of 17 astronaut candidates on 23 November.

Six members of the class will now undergo 12 months of basic training. Two people from this group are from the UK: astronomer Rosemary Coogan and John McFall, a paralympic sprinter and orthopaedic surgeon. McFall is joining the class as part of the Parastronaut Feasibility Project and will work with both ESA and NASA to see if adjustments can safely be made to allow disabled astronauts to fly in space.

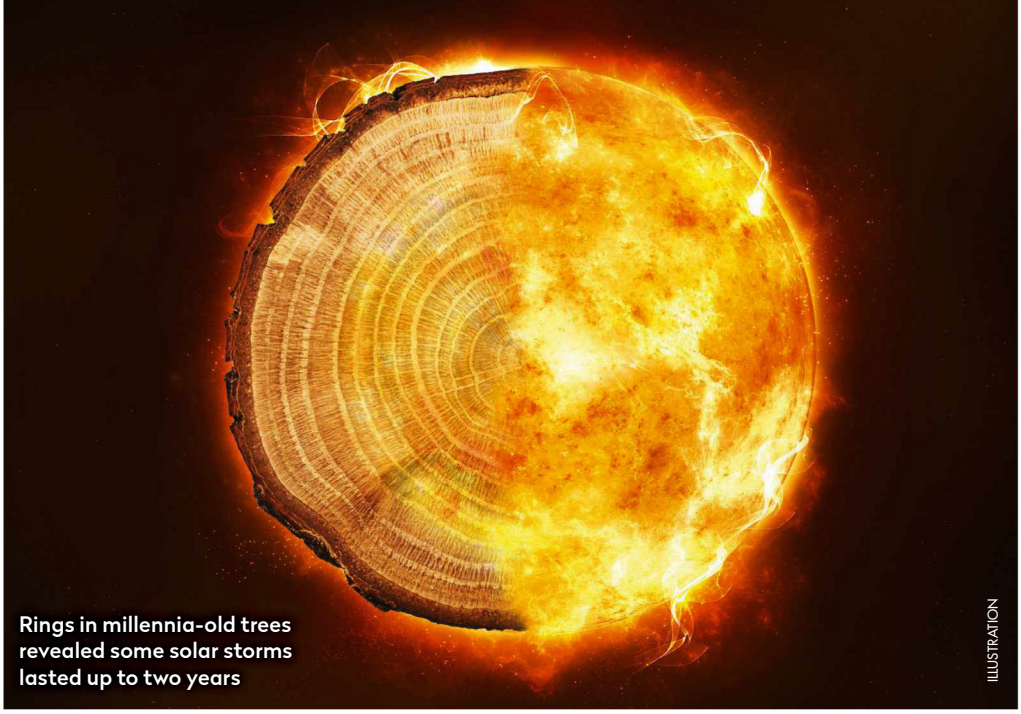
"When it was announced that they were looking for a candidate with a physical disability, I thought it was such an inspiring and thrilling opportunity," McFall said at the announcement. "I felt compelled to help ESA answer this question – can we get someone with a physical disability to do meaningful work in space? I think I can bring lots to the feasibility study, but I think I can bring inspiration. Inspiration that science is for everyone, and inspiration that, potentially, space is for everyone."

After basic training, the candidates will begin preparing to work on board the International Space Station and will eventually be assigned a mission flight.

The remaining 11 astronauts are ESA's first-ever reserve astronauts, including Anglo-Australian-Italian Meganne Christian. Currently, the only flight opportunities are to the ISS, but more could arise as projects such as the Lunar Gateway, Artemis and the Chinese Space Station (which ESA has run training exercises on) mature. The reserves will stay in their current careers but receive support so they can step in should a flight arise.

"This is an extraordinary time for human spaceflight and for Europe," says David Parker, ESA's director of human and robotic exploration. "After the successful launch of Artemis I with ESA's European Service Module powering Orion to the Moon, we are on the forefront of human space exploration. We are delighted to have this group of extremely talented people to continue European science and operations on the International Space Station and beyond." **www.esa.int**

JOEL SAGET/AFP VIA GETTY IMAGES, THE UNIVERSITY OF QUEENSLAND, INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA/J. DA SILVA/SPACEENGINE/M. ZAMANI, THANASIS PAPATHANASIOU



Rings in millennia-old trees revealed some solar storms lasted up to two years

ILLUSTRATION

Trees track solar storms

Ancient tree rings carry a record of huge radiation strikes

Powerful bursts of solar radiation, known as Miyake events, strike Earth around every 1,000 years, but their origin is uncertain. To track the cosmic storms, astronomers from the University of Queensland turned to an unexpected record-keeper – tree rings.

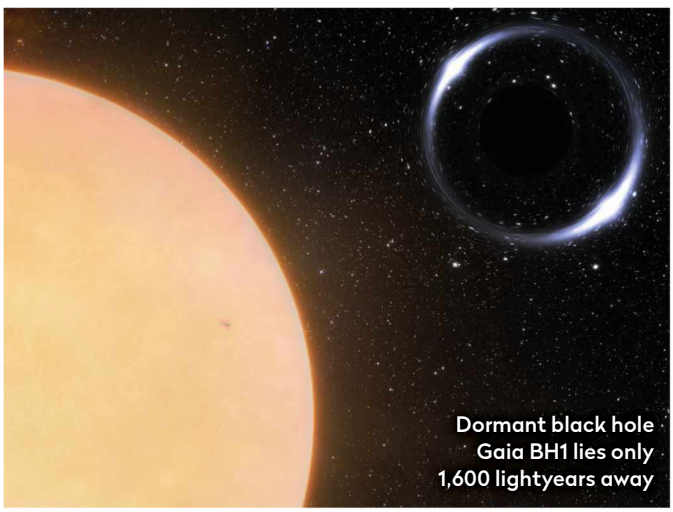
"Because you can count a tree's rings to identify its age, you can also observe historical cosmic events going back thousands of years," says Qingyuan Zhang, one of three undergraduate students who led the study.

"When radiation strikes the atmosphere, it produces radioactive carbon-14, which filters through the air, oceans, plants and animals, and produces an annual record of radiation in tree rings."

The team found Miyake events last much longer than expected, some even going on for one or two years. "Rather than a single instantaneous explosion or flare, what we may be looking at is a kind of astrophysical 'storm' or outburst," says Zhang. **www.uq.edu.au**

Earth's closest black hole revealed

A stellar mass black hole just 1,600 lightyears away has set a new record for the closest known black hole. Its presence was revealed after ESA's Gaia space telescope observed the unusual motion of its stellar companion, a Sun-like star. Closer inspection of the star's motion revealed it was orbiting around an unseen black hole with a mass 10 times that of our Sun.



Dormant black hole Gaia BH1 lies only 1,600 lightyears away

ILLUSTRATION

"This is the first unambiguous detection of a Sun-like star in a wide orbit around a stellar-mass black hole in our Galaxy," says Kareen El-Badry from the Center for Astrophysics, Harvard and Smithsonian, who led the study.

The stellar pair, called Gaia BH1, are about as far apart as Earth and the Sun, leaving astronomers struggling to explain how the star managed to survive the hypergiant phase its companion must have gone through before collapsing into a black hole.

"It is interesting that this system is not easily accommodated by standard binary evolution models," says El-Badry. "It poses many questions about how this binary system was formed." **www.gaia.ac.uk**

NEWS IN BRIEF

Spirits in the sky

NASA's new citizen science project, Spritacular, is calling on all astrophotographers to submit their photographs of electrical phenomena in the upper atmosphere, such as sprites and other Transient Luminous Events, with the aim of creating a database researchers can use to study them. If you have any images that you'd like to contribute, visit **spritacular.org**.

Anti-aging planets

Hot Jupiters can give their stars a youthful glow. A new study found some planets are large and close enough to create tidal forces in their star, making it spin more quickly. This increases solar activity, producing an abundance of X-rays usually only seen in more youthful stars.

Golden fossils

The Milky Way's gold-rich stars – those abundant in elements heavier than iron – were formed in dwarf galaxies over 10 billion years ago, according to recent simulations. These dwarfs galaxies were the building blocks of the Milky Way, and so these golden stars could be used as a fossil record of our Galaxy's evolution.

NEWS IN BRIEF


ILLUSTRATION

Oldest planetary remains discovered

The remains of the oldest known rocky planetary system have been found around a 10.7-billion-year-old white dwarf, WDJ2147-4035. The star would have ripped apart its planets during its red giant phase, and this debris is now falling onto the star's surface. Researchers used spectroscopy to detect the spectral fingerprint of this pollution.

Listening out for new planets

Astronomers could soon have a novel tool for tracking down exoplanets – listening for the radio signals given off by stellar winds interacting with a planet's magnetic field. A recent test of the technique found signals coming from 10 dwarf stars, though it has yet to be confirmed if these actually host planets.

UK Spaceport licence granted

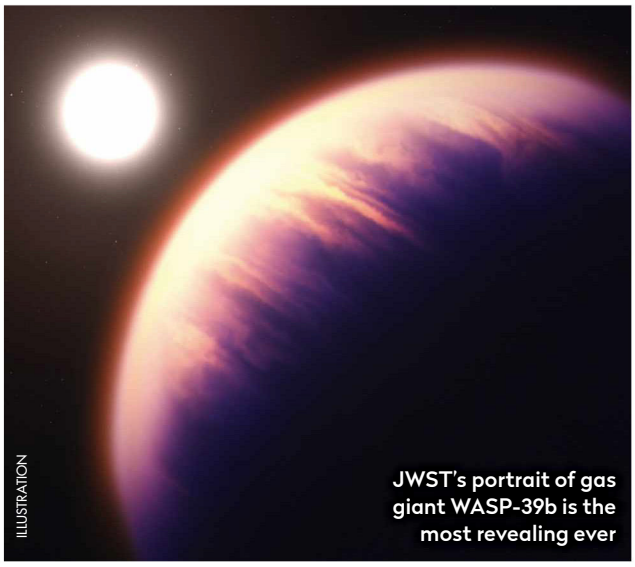
The Civil Aviation Authority issued the first-ever UK spaceport license to Spaceport Cornwall on 16 November 2022. The facility's first horizontal rocket launch will be of Virgin Orbit. **See page 62** for more details.

UNIVERSITY OF WARWICK/DR MARK GARLICK; DOE/FNAL/ DECAM/CTIO/NOIRLAB/NSF/AURA/J. DA SILVA/SPACEENGINE

BULLETIN

JWST fully unveils exoplanet atmospheres

Planet's chemistry laid bare in unprecedented detail



ILLUSTRATION

JWST's portrait of gas giant WASP-39b is the most revealing ever

For the first time, astronomers have been able to see the full chemical profile of an exoplanet's atmosphere, thanks to recent observations by the James Webb Space Telescope. The spectra revealed dozens of chemicals within the atmosphere of WASP-39b, including sulphur dioxide. The compound has never been seen on an exoplanet before and is created during chemical reactions triggered by the star's high-energy light.

"This is the first time we see concrete evidence of photochemistry – chemical reactions initiated by energetic stellar light – on exoplanets," says Shang-Min Tsai from the University of Oxford, who was lead author on one of the five papers already written on the observations.

The planet is a gas giant orbiting its star eight times closer than Mercury orbits the Sun, and is located just 700 lightyears away from Earth. The intense heat and close proximity to Earth make it the ideal target for investigating how stellar radiation affects planetary atmospheres.

webb.nasa.gov

Hidden hazardous asteroid brought to light

The largest potentially hazardous asteroid discovered in eight years has been found hiding in the inner Solar System, along with two other large asteroids.

Astronomers believe they have already located over 95 per cent of near-Earth asteroids over 1km in diameter, which would have a global effect if any hit our planet. But finding the elusive last five per cent has proved challenging.

"Only about 25 asteroids with orbits completely within Earth's orbit have been discovered to date because of the difficulty of observing near the glare of the Sun," says Scott S Shepard from the Carnegie Institution for Science, that led the recent discovery.

In the hope of finding these, Shepard's team observed during 10-minute windows each twilight when the asteroids were above the horizon and the background sky was dim enough to see them. The team found the space rocks using the Dark Energy Camera, which covers a wide field of view with great sensitivity.


ILLUSTRATION

Three near-Earth asteroids were spotted hiding in the glare of the Sun

Two of the asteroids revealed orbits comfortably far away from Earth, but the third – 2022 AP7, measuring between 1.1km and 2.3km in diameter – could cross Earth's orbit, though not for at least 200 years.

neo.ssa.esa.int

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Our experts examine the hottest new research

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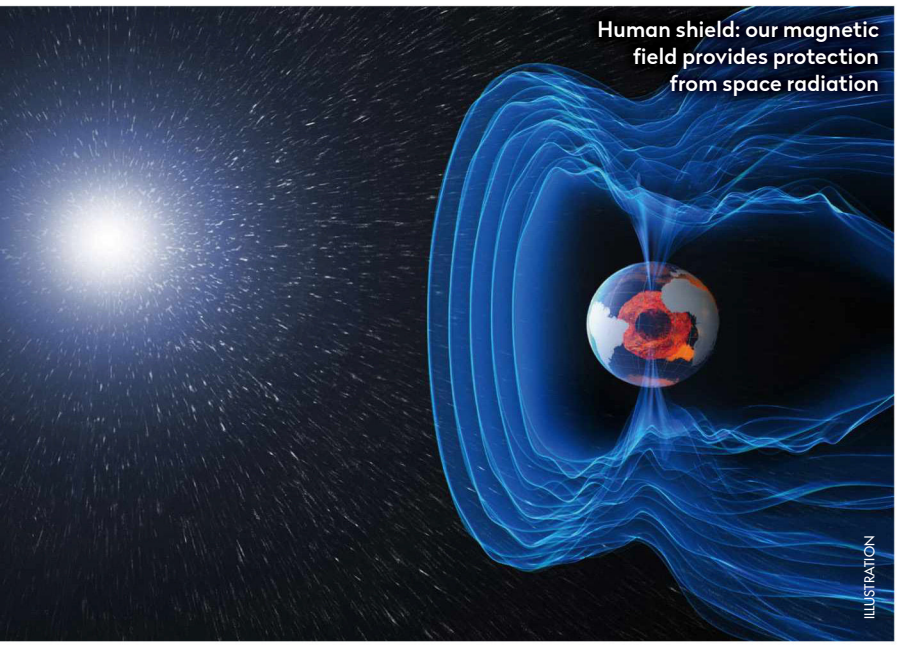


Human shield: our magnetic field provides protection from space radiation

ILLUSTRATION

ESA/ATG MEDIALAB, ICRAR

Flipping poles let in the Sun

Solar radiation at the equator surges when Earth's magnetic field reverses

Earth is under continual bombardment from energetic charged particles streaming through outer space. These are known as cosmic rays and are produced by coronal mass ejections from our own Sun, or come from beyond the Solar System, accelerated by supernovae throughout the Galaxy. When these energetic particles, travelling at near the speed of light, encounter Earth's atmosphere they trigger great showers of secondary radiation, some of which penetrates all the way to the surface. These charged radiation particles knock electrons off any atoms they pass by, causing 'ionisation' which can damage the DNA in our cells and also affect atmospheric processes.

The less energetic cosmic rays are significantly deflected by Earth's magnetic field, and so the equator receives more shielding from this particle bombardment than the North and South Poles, where the magnetic field lines dip down towards the planet's surface. Certain long-range flight paths – such as from Dubai to San Francisco – take airliners right over the North Pole and this, in combination with the high altitude, means that passengers and crew are exposed to elevated levels of ionising radiation. But variations in the flux of cosmic rays into Earth's atmosphere have also been hypothesised to influence the terrestrial climate – perhaps by affecting atmospheric water condensation and the formation of clouds. And this may be particularly significant during the periods when Earth's magnetic field reverses, and temporarily weakens.

Jacob Svensmark, in the department of physics at the University of Oxford, has been studying the most recent occasion when Earth's magnetic field underwent a reversal. This event, known as the Brunhes–Matuyama reversal, occurred around 780,000 years ago, and the big question is what impact this might have had on the ionisation within the atmosphere from cosmic rays. Svensmark used computer models to calculate atmospheric ionisation around the world as he varied the simulated magnetic field.

As you might expect, he found that the increase in ionisation during the reversal was most pronounced around the equator of the planet. But Svensmark was able to calculate this enhancement in the ionisation rate to be about 25 per cent at the equatorial surface as the magnetic field weakened, and over six times higher in the upper atmosphere. In contrast, he found almost zero change in polar regions, where cosmic rays already have much easier access. Overall, his model showed a 13 per cent increase in ionisation at sea level around the globe and roughly a doubling at the top of the atmosphere.

> ***"The increase in the ionisation rate was about 25 per cent at the equatorial surface as the magnetic field weakened"***

Svensmark notes that there appear to be correlations between the flux of cosmic rays reaching Earth's atmosphere and the climate, although it is not entirely clear what mechanism might cause this. But if this is a real effect, it is important to understand the changes in the ionisation of the atmosphere during reversals of the magnetic field. Over the past 200 years, Earth's magnetic field has weakened by about nine per cent, which could indicate that another pole reversal is coming. This isn't the cause of current global warming, but it could still have an important influence on our future climate.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Atmospheric Ionization Rates During a Geomagnetic Reversal* by Jacob Svensmark
Read it online at: arxiv.org/abs/2209.10104

Milky Way was hiding a galaxy cluster

Dust from our own Galaxy blocked the region from view – until now

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Since as far back as William Herschel, astronomers have wrestled with the problem of studying the Milky Way Galaxy while sitting within it. When creating his own map of our Galaxy, he was led astray by dust within the disc, which blocked the light of distant stars. This made it appear as if the Sun was at the centre of the Galaxy's flattened disc, rather than on the edge as we now know.

When his son, John Herschel, mapped the position of nebulae in the sky, producing what would become the NGC, or New General Catalogue that we still use today, it didn't take long for people to notice that nearly a fifth of the sky was missing, with vast swathes devoid of objects. The great 19th-century populariser Richard Proctor called this the 'zone of avoidance', a fabulous term for the region. It followed the band of the Milky Way in the sky, where our Galaxy obscures any distant object.

The zone of avoidance has been slowly chipped away at over the subsequent century. Radio astronomers can help, and most of the reconstructed maps you've seen of the Milky Way extrapolate from their maps. But so too can looking in the infrared, a wavelength that passes through the dust with little issue. This is exactly what this month's paper does.

We know, from previous observations and from analysis of how our Galaxy moves, that there must be clusters of galaxies in the zone of avoidance. One, dubbed the Great Attractor, seems to be gravitationally pulling us towards it and is a major influence on how the Milky Way and its neighbours are moving.

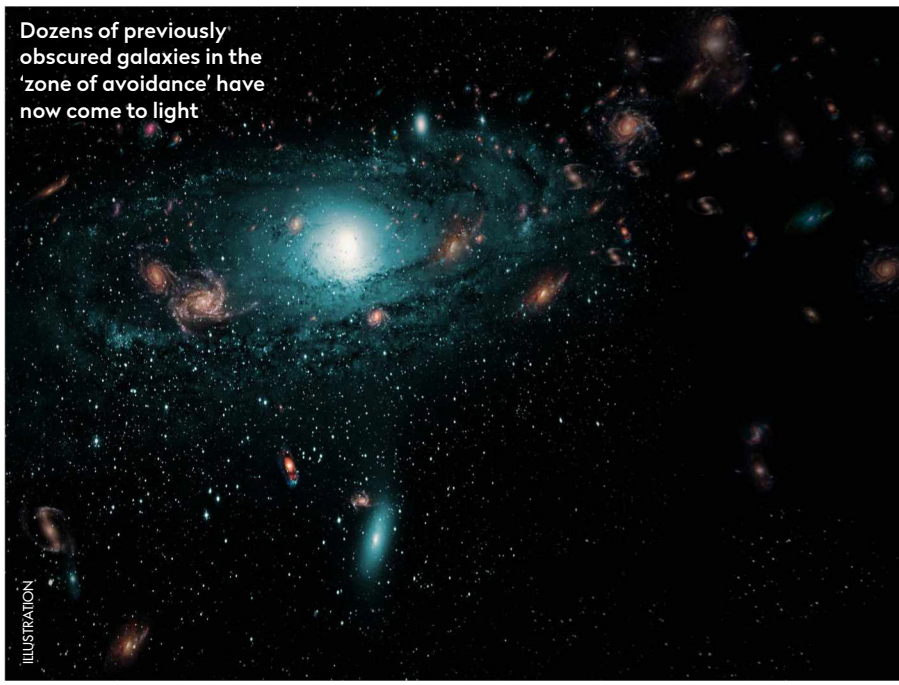
To shed some light on this mysterious region, the authors, led by Daniela Galdeano of the National University of San Juan, Argentina, use data from a deep infrared survey conducted with VISTA, the small survey telescope that shares a site with the much grander VLT in the Atacama desert in Chile. VISTA had been returning to the same patch of sky over and over again to look for variable stars, but the images could also be stacked together to provide deep coverage of the infrared sky. These revealed 58 possible galaxies in an area just one-fifth of the size of the full Moon.

> ***"The images provided deep coverage of the infrared sky. They revealed 58 possible galaxies in an area one-fifth the size of the Moon"***

The giant 8.1-metre Gemini South Observatory telescope was used to follow up five of these, showing that these blobs in the VISTA images really were galaxies, forming a cluster about 2.5 billion lightyears away. These seem to be perfectly normal galaxies, on average a bit more massive than the Milky Way, and mostly at the point where they are beginning to stop star formation.

This last finding may be an artefact of how the selection was done. Galaxies that have stopped star formation, being devoid of the sparkle of young, massive, blue stars, are red and might therefore be more likely to be picked up by surveys made in the infrared. More massive galaxies also seem to reach this stage first, but with many other candidate galaxies as yet unexamined it seems we may be looking at a substantial cluster.

The cluster has been given the unprepossessing name of VVVGCl-B J181435-381432 and is another little bit of the cosmic map, until now hidden behind the Milky Way's bulge, that has been coloured in.



Dozens of previously obscured galaxies in the 'zone of avoidance' have now come to light

ILLUSTRATION

Chris Lintott was reading... *Unveiling a New Structure Behind the Milky Way* by Daniela Galdeano et al. **Read it online at: arxiv.org/abs/2210.16332**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

Science-heavy shows like *The Sky at Night* require a lot of research, and it's up to people like **Chris Johnston** to make sure they get it right

▲ **Multiple Chris Lintotts debate the nature of the multiverse in November's Multiverse of Mystery episode of *The Sky at Night***

Working on *The Sky at Night* has been quite unlike any other experience I've had in TV. Before this I was a researcher on Brian Cox's landmark series *Universe*, but despite having similar content, the two shows couldn't be more different. On *Universe* I spent most of the year behind a desk, making sure our scripts all stayed scientifically accurate. In just a few months on *The Sky at Night* I've been on a road trip to meet scientists working on the James Webb Space Telescope, I've been on set with a live studio audience filming our Question Time episode, and I've explored obscure mysteries in the multiverse with four Chris Lintotts. There aren't many shows that can offer that kind of variety, especially in the world of astronomy.

As a researcher, I normally spend my time contacting expert contributors, fact-checking scripts and sourcing extra footage and images for the editors. On a show like *Universe*, with a huge team, a researcher is a small but vital cog in a much larger machine. On *The Sky at Night* – which usually has a team of only five or six – I've had a brilliant opportunity to experience far more of the TV-making process. While I've still had to cover those normal duties, on *The Sky at Night* I was also able to develop stories and write parts of the script and, most importantly, I've been able to get out and about on shoots and get involved in the practical side of creating TV shows.

Going public

Of all the experiences I've had on the series, working on the annual Question Time episode has to be my highlight. A few weeks earlier, we had been filming in Pete Lawrence's back garden with two cameras, a couple of contributors and a six-person crew.

BBC X 5, GETTY

Chris Johnston is a TV researcher who specialises in astrophysics documentaries

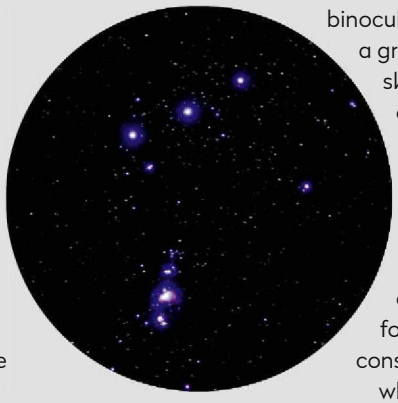
Suddenly I was on a massive set with six cameras, a crew of 20 or more, and a full studio audience. Seeing first-hand how a shoot like that is run is truly awe-inspiring, and also pretty nerve-wracking. But I think the best thing about that episode was being able to involve the fans in the show. We had a great response to our call for questions, and getting to see the people that we're making the show for ask the presenters their questions was a rare view of the power of TV. What was particularly rewarding was seeing questions coming in from people of all different ages. One of the main goals of science TV is to get people interested and engaged in science, so seeing people young and old contribute means we must be doing something right.

I've been incredibly fortunate not just to work on a show as interesting and illuminating as *The Sky at Night*, but also to have the privilege of working with an amazing small team that's been able to put out an engaging and informative show every month – as well as a group of brilliant presenters who all love the show and genuinely have its best interest at heart. I hope the episodes we've put out this year have lived up to the 66-year history of *The Sky at Night* and that this brilliant show runs for many more years to come.

Looking back: The Sky at Night

11 January 1978

For decades, *The Sky at Night* has helped astronomers find out what's up in the night sky that month, but it has also allowed seasoned astronomers to pass on their best observing tips. In the 11 January 1978 episode, Patrick Moore took the opportunity to dispense advice about a key piece of any astronomer's kit – a pair of binoculars.



▲ **Orion's Belt and dangling Sword, as popular a binocular target today as it was in 1978**

Today, you can buy a fairly good astronomical telescope for an affordable price, but the same was not true in the 1970s. While mass-produced telescopes had brought the price down under £1,000, they were still beyond the budget of many. But Patrick was always keen to point out there was no need to spend vast sums on a telescope when binoculars could show you a great deal of the night sky, and they are still considered to be the best way to get started in astronomy.

In this episode, Patrick took a tour of the winter sky, focusing on the constellation of Orion, which is filled with many binocular targets. Orion's Belt will happily fit in the field of view of a pair of 10x50s, giving you a closer look at this trio of stars. Then, a sweep down into the Sword of Orion will reveal the wonderful open cluster NGC 1981 and, just below that, the Orion Nebula. The nebula is a popular telescope and photography target, but binoculars can still reveal a lot of detail, especially if you look just off to one side of the object, a technique known as averted vision.

The Sky at Night

Explore the cosmos with Brian Cox

Chris, Maggie and Pete are taking a break this month, meaning there is no episode of *The Sky at Night* in January. In the meantime, there's plenty of space and astronomy content available on the BBC iPlayer, including an archive of Professor Brian Cox's cosmic investigations. They include: 2021's *Universe* series; an exploration of the Solar System in *The Planets*; a look at the Perseverance rover mission in *Seven Days on Mars*; and a 100th-episode TV special of the popular Radio 4 science panel show, *The Infinite Monkey Cage*.

bbc.co.uk/iplayer/group/p09z0tj9

▲ **Brian Cox explores the cosmos in a range of programmes available on the iPlayer**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize:
two Philip's titles

The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2023* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

MATTEO COLOMBO/ISTOCK/GETTY IMAGES

World in motion


Star trails illustrate Earth's rotation on its axis

I welcomed my latest issue of *BBC Sky at Night Magazine* and that it showed me how the heavens move each month and what I should look for, so well done – please keep up the good work!

I was given a gift of a Schmidt-Cassegrain telescope about 18 years ago, but was unable to set it up with its Go-To function, and have never seen any identified object in the heavens with it! I have now joined a local astronomical society where I hope to find an enthusiast to help me. My key beginner's problem is understanding the basic inter-relationships of the heaven's components. I could understand an orrery if I had one, but would then seek to understand that in month X the axis of Earth is pointing to Polaris from position Y, and therefore the heavens appear to move in manner Z.

I also read on your website that the night sky shifts forwards by four minutes each night, and don't understand what is meant by 'forwards'.
Geoff Lezemore, Devon

We're glad you enjoy the magazine, Geoff! In answer to your questions, Earth's axis points towards Polaris year-round; stars rise above the eastern horizon and move across the sky in a westerly direction during the night, before setting over the western horizon. Stars also rise, cross the sky, and set four minutes earlier each night, because of Earth's orbital motion. ***– Ed.***

Tweet

Pete Collins
@diamondskies99 • 14 November
Mars + Aldebaran + a bit of 'artistic license' ;-) Red planet Mars last night and red giant star Aldebaran in Taurus. I've put spikes on them to emphasise their similarity in colour. @GoStargazing @skyatnightmag

Gazing gift

I'm looking to purchase a first telescope for my 12-year-old son for Christmas. He's had a look himself and identified the Celestron AstroMaster 114EQ reflector telescope as the one he wants. Can you advise if this is a suitable starter scope for a young boy?
Helen Gregor, via email

The Celestron AstroMaster is a good beginner's scope that's well put together. The equatorial mount that comes with it has quite a steep learning curve. If you want a telescope that is quicker to set up for your son, you might consider a tabletop scope like Sky-Watcher's Heritage 130P FlexTube Dobsonian telescope for around the same price. Happy stargazing! ***– Ed.***

Taking shape

If it all started with the Big Bang and we are now 13.8 billion years after, are we on the edge, or is there something further out that is more than 13.8 billion lightyears away from the Big Bang? Also, is there light from the other side of the Big Bang? And then there is the question, did the Big Bang go in only one direction or in a spherical format?
Willy and Olive Peel, via email

The exact shape of the Universe is one of the big questions of cosmology, but we do know the Big Bang caused the Universe to expand

▲ Graham inadvertently caught the Moon's Jewelled Handle clair-obscur effect, where light hits the ridge of the Jura Mountains

in every direction. Because this expansion is of the fabric of space-time itself, things that are very far from us can be further than 13.8 billion lightyears away, since the space the light has travelled through has expanded behind it. For example, light reaching us from 13.78 billion years ago would be from something that is now 41.6 billion lightyears away. **– *Ed.***

Happy accident

In her *Sky at Night Magazine* Masterclass webinar, 'The Moon: Up Close with our Celestial Neighbour' on 27 October, Charlotte Daniels showed us a photo in which she had captured the Lunar X without realising until later. After her talk I looked through my Moon photos and discovered that I'd captured (see above) the Jewelled Handle unawares!

Graham Easby, via email

Weight loss

What would be the effect if we as a species were to go to the Moon and undertake mining? I've been wondering whether this would cause the mass of the Moon to decrease, and whether this decrease in mass would then accelerate the movement of the Moon away from Earth, which I assume would affect the tides.

Gerard Blake, Neilston

The Moon's mass is 73,000,000,000,000,000,000 (73 quintillion) tonnes, so it ▸

ON FACEBOOK

WE ASKED: What's your favourite deep-sky object?

Matthew Terrell NGC 7331. The shape and the colour. I've got lots of hours on it. It really is my favourite DSO.

Carol Miller The Orion Nebula. Orion is my favourite winter constellation and to just see Orion's nebula without the need of a telescope or a pair of binoculars gives me goosebumps every time.

Tony Moss I love the Pleiades, M45, whether visually or with a camera.

Proteus Meeper Globular clusters.

Wendy Castle Sirius, the brightest, shiniest and most twinkliest star of all.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

Is there a mount that I can use for both a telescope and a camera?

EAN BRUCE

▲ A ball head can fix your camera to your tube rings

Most astronomy mounts are designed solely for use with a telescope, although there are some mounts known as 'star tracker mounts' that are designed specifically for use with cameras. However, many telescope mounts can be pressed into service as camera mounts using one of two methods.

If your telescope is supported using tube rings, it is often possible to attach a metal bar to the top of the tube rings and then attach your camera to the bar using a ball-and-socket head or monopod tilt head, like those made by Manfrotto and Benro, using a ¼-20 bolt.

If you'd prefer not to keep the telescope on the mount when using the camera, ensure that you choose a mount that uses a Vixen- or Losmandy-style dovetail clamp. You can then use the same head as above but attached to the dovetail bar instead of a standard metal bar, which you can then fit directly into the dovetail clamp.

Steve's top tip

What is eye relief?

Eye relief is the fixed distance from the curved surface of an eyepiece's outermost lens – the eye lens – to the point at which you can observe the whole field of view without vignetting – the exit pupil.

The longer the eye relief, the more comfortable the observing experience becomes. If you suffer from astigmatism, wearing corrected spectacles while observing can generally be beneficial – but wearing spectacles forces your eye further from the eye lens, so spectacle wearers in particular should choose eyepieces with a long eye relief.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

BBC Sky at Night Magazine is published by Our Media Ltd (an Immediate Group Company) under licence from BBC Studios, which helps fund new BBC programmes.

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SUBSCRIPTION RATES
Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

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Audit Bureau of Circulations
23,082 (combined; Jan–Dec 2021)

ISSN 1745-9869

Instagram

kon_astro • 6 November

Jupiter double transit from Europa and Ganymede on 26 October. I quite like the mirror symmetry between the shadows and moons. 8" Dob, manual, ASI462MC, 2.5x TV Powermate
#telescope #jupiter #planetary
@bbcskyatnightmag

▸ would take hundreds of millions of years of mining to remove enough material to alter the Moon's distance from Earth. ***– Ed.***

Energy levels

I have been pondering over the electromagnetic wave energy coming from suns throughout the Universe, not just ours. I know this energy gets absorbed by various atoms, but is there a region of space where all this electro-magnetic energy gathers, and the form of energy changed somehow because of this?
Franklin Gordon, via email

As far as we know, Gordon, electromagnetic energy travels in all directions equally. Some gets absorbed by the gas throughout the cosmos; the rest all mixes together to become a background soup of energy. ***– Ed.***

CORRECTIONS

In the Bulletin section of our December issue, in the story 'First space launch from UK soil', Virgin Orbit's 747 aircraft will fly to an altitude of 10,000m not 10,000km; and in 'Chinese Space Station completed', taikonauts will conduct an ultra-cold experiment to cool atoms to one billionth of a degree above, not below, absolute zero.

SOCIETY IN FOCUS

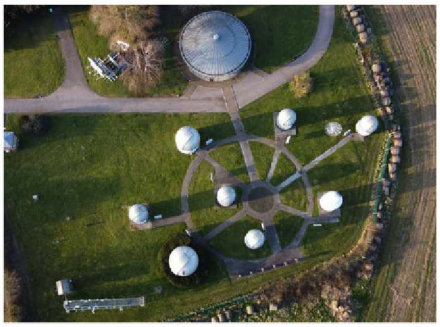
Luton Astronomical Society was founded in late 1969, around the time of the Apollo 11 Moon landing. Our members are our greatest asset, of course, but we can boast a half-meter-aperture reflecting telescope in our observatory at Putteridge Bury near Luton as a singular attraction. This observatory, dedicated on 10 October 1992 by Sir Patrick Moore, provides stunning views of those 'faint fuzzies' at magnitude 14 and greater. Our members share the wonders of the night sky with the public at least monthly, in addition to our regular members' observing events. Post-pandemic, in 2021 our observatory hosted 120 astronomers under age 12. In 2022 our members provided lectures on the James Webb Space Telescope to over 500 students at local schools, as well as 90 STEM students at the University of Bedfordshire in Luton.

Like most organisations, we had to restrict activities during the COVID pandemic. Our solution was to establish a virtual meeting forum using Zoom as a substitute for our monthly meetings at Putteridge Bury. We now have a significant number of virtual members who live well outside the Luton area, in addition to our local membership. To accommodate both local and virtual members, a typical month includes both a Zoom meeting mid-month and an in-person meeting near the month's end, which is broadcast on Zoom to our virtual members as well. The emphasis going into 2023 will include Mars, Jupiter, Saturn and 'the usual suspects' in the winter night sky as we approach British Science Week 2023.
Larry Jones, Education Officer, Luton Astronomical Society
▸ www.lutonastrolink.org.uk

▲ Luton AS often hosts schools and groups at its observatory at Putteridge Bury

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON



UNIVERSITY OF HERTFORDSHIRE, CALUM STOTT X 2

Bayfordbury Observatory open evening

Bayfordbury, Hertfordshire, 27 January, 5:30pm

The telescopes of the observatory will be equipped with cameras to better show off faint galaxies and planetary detail on this open evening, when anyone can have a go, meet the researchers and hear expert talks. £10 adults, £5 concessions.
www.herts.ac.uk/bayfordbury/bayfordbury-observatory

Worthing observing night

Worthing, West Sussex, 7 January, 7:30pm

Formed in 2008, Worthing Astronomers run several observing events each year for members and non-members alike to get hands-on with telescopes and enjoy the night sky. £3 entry; free for first-timers.
www.worthingastronomers.org.uk

Visit the Spaceguard Centre

Knighton, Powys, all month

This working observatory is dedicated to addressing the risks from asteroids and comets that stray too close to Earth. Tours are run throughout the year, giving the public a chance to see behind the scenes at this important facility. £8 for adults, £5 for kids. For dates and times, visit **spaceguardcentre.com**

Aberdeen stargazing

Westhill, Aberdeenshire, 18 January, 7:30pm

An evening of appreciation of the night sky with Aberdeen West Astronomy Group, who meet every month at Garlogie Hall. Anyone with a telescope or binoculars is welcome to attend. No fee, but donations are welcome.
www.aberdeenwestastronomy.co.uk

PICK OF THE MONTH

▲ Enjoy an evening of light-pollution-free stargazing inside the Yorkshire Dales National Park

Stargazing Beneath Ingleborough

Ingleborough Cave, Clapham, North Yorkshire, 14 January, 6:30pm

Cold, clear winter nights make for excellent stargazing conditions. In this guided tour of the night sky, astrophotographer Pete Collins will give a talk at the Old Sawmill Cafe on the wonderful celestial sights to be seen, before heading outside for a short walk up the trail and a spot of stargazing over the Yorkshire Dales National Park. A Dark Sky Reserve, with constellations, star clusters, galaxies and planets all on show, the park has large areas that are completely free of local light pollution. Tickets cost £15 per person and booking is essential.
www.yorkshiredales.org.uk/whats-on

Liverpool Young Astronomers

Pex Hill Visitors Centre, Cheshire, 19 January, 7pm

The extremely popular junior wing of Liverpool Astronomical Society meets at the Leighton Observatory in Pex Hill to observe through telescopes, take astrophotos of various objects in the night sky, have interesting talks and take part in other astronomy-related activities. £1.50 per child.
liverpoolas.org/young-astronomers-club

Observing at Delamont Country Park

Killyleagh, County Down, 20 January, 7pm

The Irish Astronomical Association's evening of stargazing, open to everyone. Telescopes supplied, including larger models for viewing deep-sky objects.
irishastro.org/observing-programme

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FIELD OF VIEW

Waiting for Artemis

Hope, hold-ups and highs – such is the life of a spaceflight fan, says **Niamh Shaw**

Rollout night in March, when hopes were high for an August launch

Waiting game: Niamh stands by for lift-off (crossed fingers not shown)

Niamh Shaw is a space journalist and science communicator

At 3pm on St Patrick's Day, 17 March 2022, I found myself in the media pen at NASA Kennedy Space Center, standing alongside US and foreign national press. We waited patiently, hoping for that first glimpse of the enormous Space Launch System and Orion capsule assembly that was soon to roll out of the Vehicle Assembly Building. When it did finally crawl past us at around 8pm, I could barely take it in. It was enormous.

Four months later, NASA announced that Artemis I – the first mission in the agency's new lunar landing programme – would launch on 29 August. I made my travel plans and returned to Cape Canaveral.

The big night finally arrived. I was on site at about 10:30pm, preparing for a launch window that would last between 8:42am and 10:42am. I'd brought way too much food and camera gear with me – I wasn't sure what I'd need, so I took everything. The excitement was palpable in the media centre; it was the busiest I'd seen it. I was too late to get a desk, but I found a chair and used it as my base for the night. NASA, ESA and CSA astronauts walked about in packs. There were Artemis-branded moon pies, donuts, baseball caps and other merchandise laid about the newsroom.

I set up my camera on the lawn around 11pm. While a spate of warm rain wasn't that bad outside, back in the air-conditioned newsroom I sat uncomfortably chilly in my damp clothes all night. Silence spread across the room every time there was an update from ground control, and we huddled around the monitor to determine how things were progressing. Around 1am, problems started to crop up as attempts were made to fill the liquid hydrogen tank. One issue was resolved; another would emerge. Creeping slowly towards launch time, I tried to remain hopeful that it would go ahead. I headed out to the lawn to capture the sunrise and wait.

Around 8:30am NASA stepped down from its decision to launch. We had all expected as much. I packed up my gear and headed back to the hotel. Luckily, a new launch date was announced for 2 September. There was less media this time, and a little less excitement too. No moon pies or donuts either, but at least it wasn't raining. However, the same liquid hydrogen leaks returned and, once again, launch was cancelled. I was sad leaving the lawn that morning, packing up my gear. I took one last photo of the rocket and hopped on the bus.

On 16 November at 6:47am I finally got to see Artemis I lift off, but this time via an online feed. It was magnificent, but bittersweet for me. You can schedule launches, but in spaceflight nothing is ever guaranteed. Safety has to come first. But with the launch of Artemis I, a new era in spaceflight has begun, and I'm thankful I got to be a part of it in some small way. All I can do is hope I'll be there in person for the next one!

NIAMH SHAW X 3

BBC

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Sega Toys Homestar Flux

Satin Black

Imagine enjoying the sky full of stars while sitting on your sofa. This dream can become reality with the Sega Toys series of home planetariums.

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Brilliant glass lenses and our brightest LED to date make everything look vibrant and sharp.
The indicated edges of a lunar crater surrounding the lens finish the look.

SEGA TOYS flx

www.segatoys.space 174GBP

Stargazing and spaceflight in 2023

Ezzy Pearson kicks off the year with a look at the unmissable sights and pioneering flights that lie in store for us in 2023

Look ahead: from meteors to Moon landings, there's lots to look forward to this year

M-GUCCI/ISTOCK/GETTY IMAGES, NASTCO/ISTOCK/GETTY IMAGES

A super year for the Moon

Spectacular lunar events to see in 2023, both at night and during the day

The Moon is a wonderful thing to observe at any time of year, but there are times this year when you will want to pay special attention to our nearest neighbour.

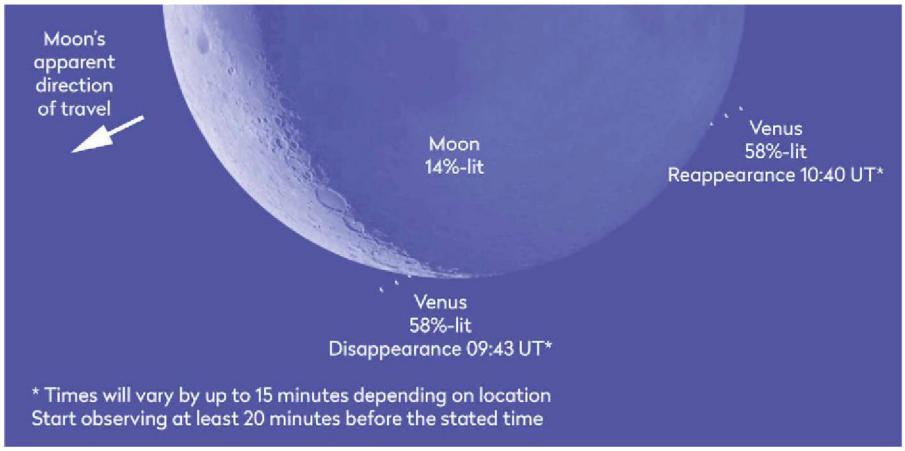
Several planets will be occulted by the Moon in 2023, meaning their path across the night sky passes behind the Moon, temporarily blocking it from view. The first is on **1 January**, when the occultation of Uranus will be visible across much of the UK (**turn to page 47** for more details).

On **17 May** it is Jupiter's turn to be occulted, though only for those in Scotland and the northern tip of Ireland – for the rest of the UK it will be a near miss. To make the observation even more challenging, it will be in the middle of the day at 13:40 BST (12:40 UT), but both the Moon and Jupiter are bright enough to be visible.

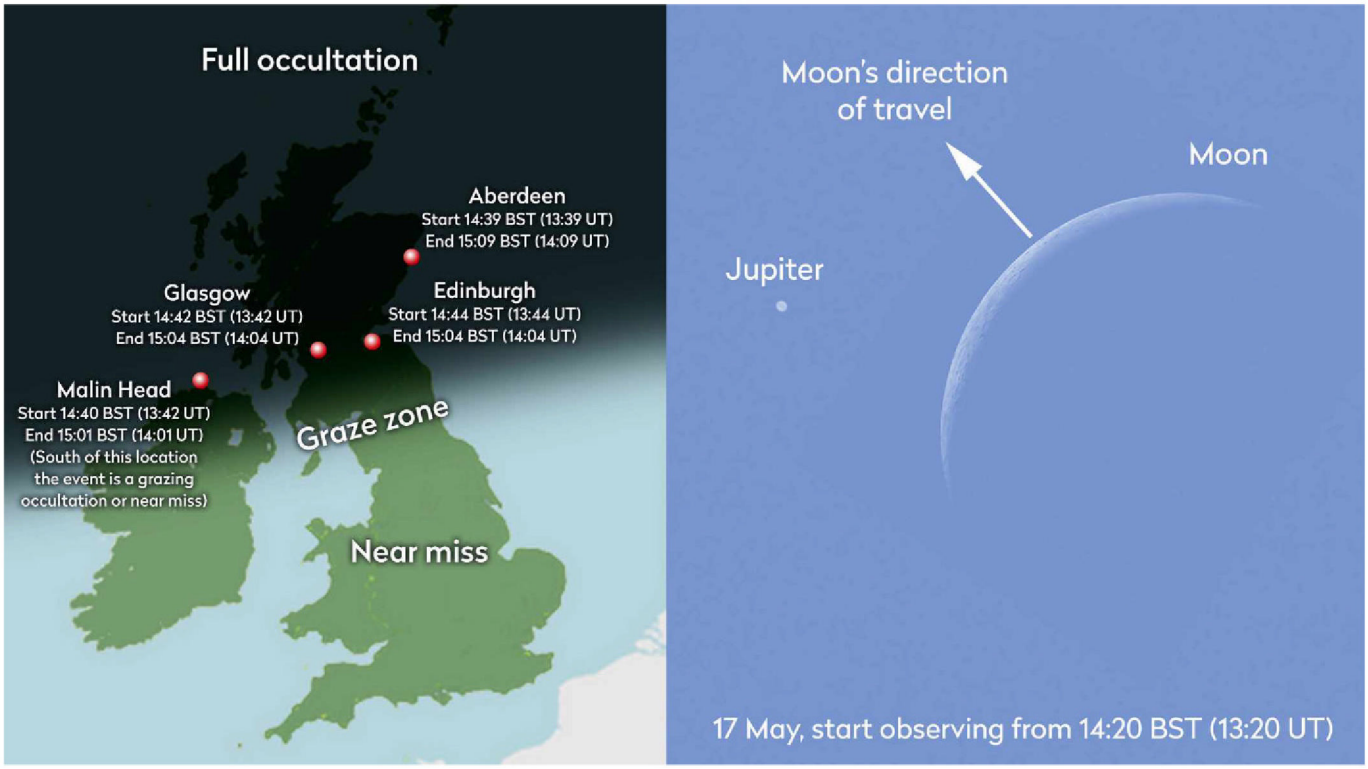
The final planetary occultation of the year is Venus on **9 November**. It will be another daylight occultation, beginning at 10:34 UT, but again, Venus is a bright mag. –4.4 and the full occultation will be visible from across the UK.

The full Moon will appear at its biggest and brightest during the summer months, when its slightly elliptical orbit means the full Moon occurs closer to Earth. The technical name for this is a 'perigee syzygy full Moon' but it is better-known as a supermoon. Unusually, this **August** there will be two supermoons in a single month, creating a Super Blue Moon. This also means there will be 13 full Moons this year, granting even more chances to take in its beauty.

▲ **The Moon will appear very slightly larger during August's two 'supermoon' full Moons**



▲ **9 November: a rare lunar occultation of Venus can be seen during the day across the UK. Venus will be showing a 58%-lit phase and appear 1/90th the apparent size of the Moon**



ALL PICTURES: PETE LAWRENCE

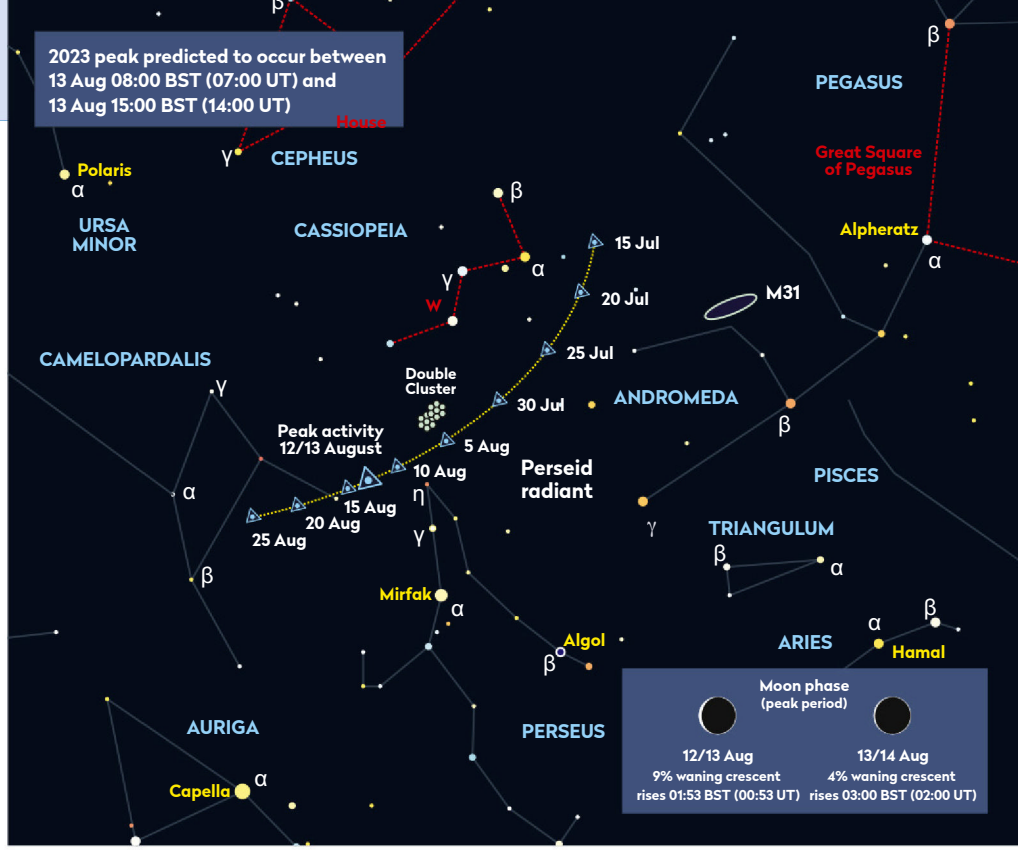
▲ **17 May: the northern part of the UK will experience a rare and challenging-to-spot daylight lunar occultation of the planet Jupiter**

Moon-free meteor showers

Moonless skies promise great meteor-watching conditions all year

In 2022, almost all the major showers were gatecrashed by the Moon, its bright light overpowering dimmer meteors, reducing the number that could be seen. This year, however, all the major showers occur near to new Moon, meaning it will be both dimmer and below the horizon for most of the night.

Another factor affecting how many meteors you can expect to see is how prolific the meteor shower is, which is measured by its Zenithal Hourly Rate (ZHR). This is the number of meteors you would see under perfect conditions, if the shower was coming from directly overhead. In reality, the number you will see will be significantly less, closer to half.



▲ **The Perseids will put on an excellent show this year, peaking around 13 August**

Here are the dates of the meteor showers where the Moon will be most favourable:

- **Lyrids, 16–25 April, peak 22/23 April, ZHR of 15-20**
- **Perseids, 17 July–24 August, peak 13 August, ZHR of 100–150**
- **Draconids, 6–10 October, peak 7 October, ZHR of 5**
- **Orionids, 2 October–7 November, peak 21/22 October, ZHR of 20**
- **Leonids, 6–30 November, peak 17/18 November, ZHR of 10–15**
- **Geminids, 7–17 December, peak 13/14 December, ZHR of 150**

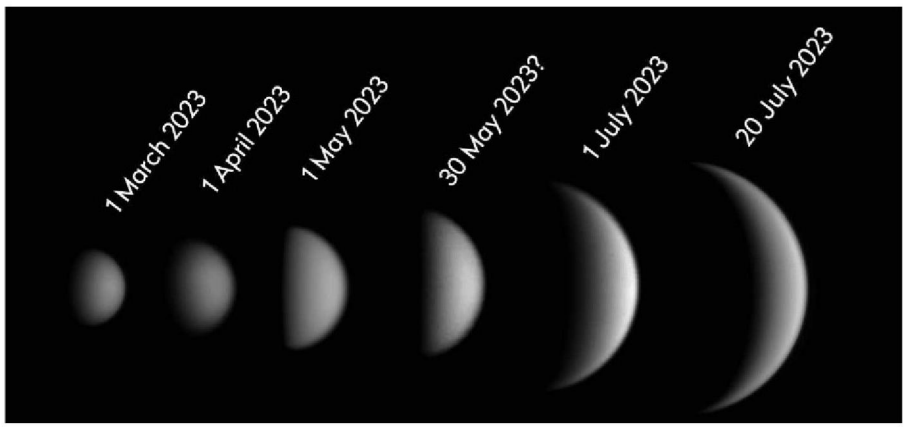
Vibrant Venus

The 'evening star' will give lots of observing opportunities in 2023

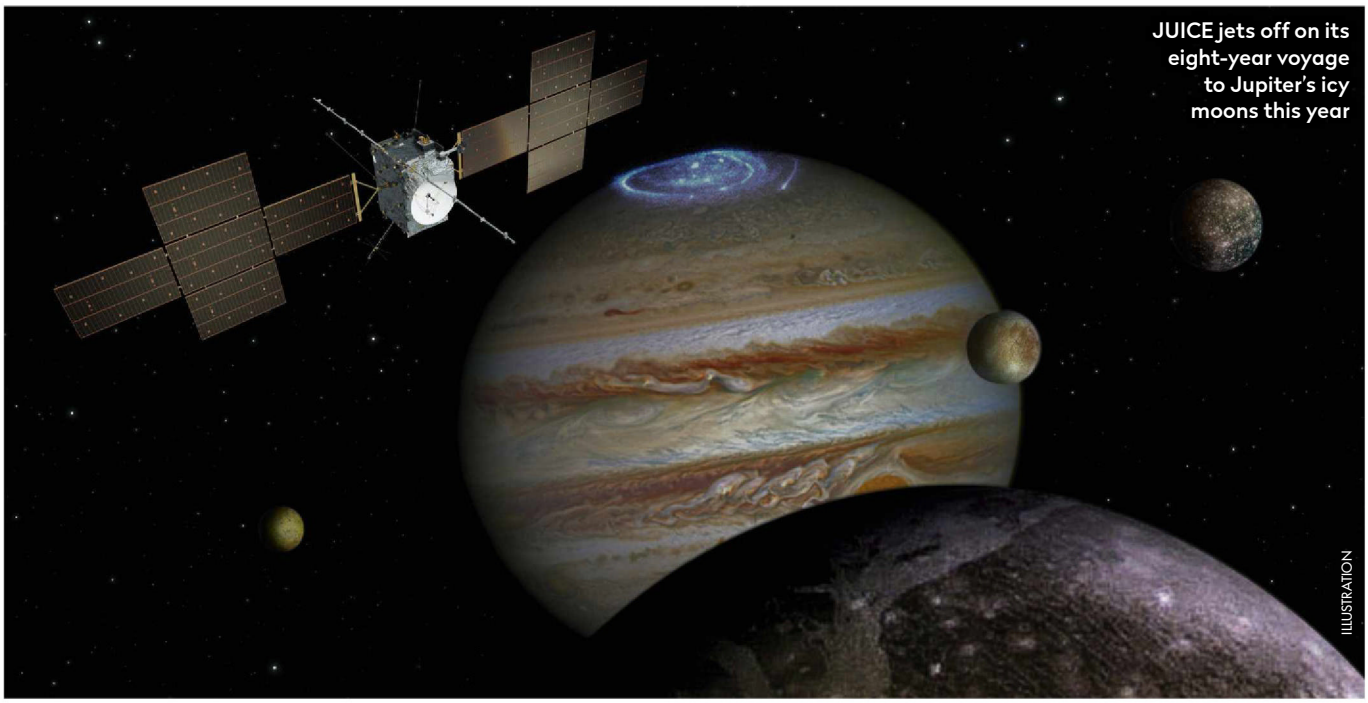
Throughout the first half of the year, Venus will be well-placed high in the evening sky. Its clear visibility makes it the perfect time to conduct a long-term observing or imaging project, such as capturing the planet's phases. The planet will start the year around 95%-lit, but slowly become less illuminated as it moves around the Sun. Around **30 May** it will appear around 50%-lit through a telescope, then will rapidly fade to just 19%-illuminated by the **end of July** when it moves into the morning skies.

Another project is to try to catch Venus as it passes all the other major planets throughout the year. The planet reached conjunction with Mercury on **29 December 2022**, but remains close by for the first week of 2023 before moving towards Saturn on **21–22 January** (see our Sky Guide on **page 47** for details). In **mid-February** it brushes past Neptune, meaning you can see the dimmest and the brightest planet at the same time. The UK will miss their closest pass, just 47 arcseconds apart, but you can see them close to each other on the evenings of **14 and 15 February**. Venus approaches Jupiter on **1 March**, passing just 0.6° away – they will be the two brightest things in the night sky after the Moon, so should be hard to miss. Later that month you will need to grab binoculars to see Uranus when it is 1.2° away from Venus. You will have to wait until **June** to complete the set with Mars, but unfortunately it will be a standoffish encounter, with the pair never reaching conjunction or getting closer than 3.6° on **1 July**.

Another meeting of note is on **10 April**, when Venus will pass south of the Pleiades open star cluster. They will both be high in the sky for several hours after sunset, giving you lots of opportunities to take a striking photo. ▸



▲ **Venus phases in the months ahead. In theory, the planet will reach its 50%-lit phase on 30 May, though the date that it appears so in a telescope may be a few days later**



JUICE jets off on its eight-year voyage to Jupiter's icy moons this year

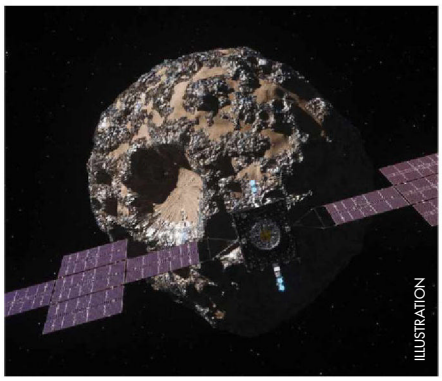
Exploring the Solar System

Several major missions blast off – and one returns to Earth – in 2023

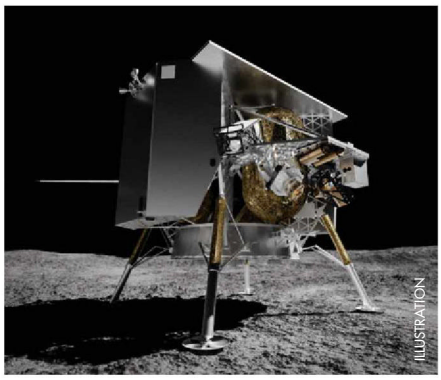
Of the three new explorers heading out into the Solar System this year, the showpiece is undoubtedly the **Jupiter Icy Moons Explorer (JUICE)**. It will be the first time that the European Space Agency has sent a spacecraft beyond the asteroid belt, and it is bound for the three largest moons of Jupiter: Europa, Calisto and Ganymede.

All three could harbour potential subsurface oceans and there have even been plumes of water seen erupting high over Europa, which JUICE will look for during its two fly-bys of the moon. It will also make 12 passes of Calisto – home of the most densely cratered surface in the Solar System, indicating the long-dead world is an ancient relic of the Solar System's creation. However, JUICE's primary target is the largest moon in the Solar System, Ganymede. JUICE will investigate all aspects of the moon's geology, from its mysterious magnetic field to its thin atmosphere. The mission's launch window is **5–25 April**, arriving at Jupiter in July 2031 and entering into Ganymede's orbit in 2034.

Later in the year, it looks set to be the autumn of asteroids, as **OSIRIS-Rex** returns with its payload of asteroid dust from asteroid Bennu on **24 September**, followed by NASA's **Psyche** spacecraft which launches for the 226km-wide asteroid of the same name in **October**. The metal-rich space rock is believed to have once been part of the metallic core of a planet destroyed in its infancy, giving a window into a part of the planets usually hidden from view. Tagging along for the ride are two 36kg **Janus probes** that will fly to two separate asteroids.



▲ **The Psyche mission promises a glimpse of the metallic core of a vanished planet**



▲ **The Peregrine lander is set to put the USA back on the Moon in early 2023**

And finally, 2023 will continue the trend of renewed interest in the lunar surface as several landers funded by NASA's Commercial Lunar Payload Services (CLPS) programme prepare for their first flights. The **Peregrine lander** from Astrobotic aims to fly in the first quarter of 2023 and carries six mini-rovers, all built by different nations. Intuitive Machines' **Nova-C** will follow soon after, heading towards the relatively unexplored lunar south pole.

CLPS was created as an offshoot of the Artemis programme, funding private companies to build lunar landers to support future human landings, and both will carry multiple NASA experiments to scout out the Moon's surface. They will also carry payloads from commercial customers, including a legged **Asagumo 'rover'** from the British–Ukrainian company Spacebit.

Also bound for the south pole is Roscosmos's **Luna 25**, which aims to analyse the composition of the lunar soil there. It is due to launch in **July**, 47 years after the Russian agency launched its last lunar lander.

ESA/ATG MEDIALAB/NASA/JPL, NASA/JPL-CALTECH/ASU, ASTROBOTIC TECHNOLOGY, ESA/ATG MEDIALAB/ NASA/ESA/CXC, BOEING

Looking into the dark

Orbital observatory duo will gaze into the depths of the cosmos


ILLUSTRATION

Euclid will scour distant galaxies on the hunt for dark energy and dark matter

Two major new space telescopes are heading into space this year, beginning with ESA's **Euclid telescope**, which will take a deep look into the Universe's dark side – dark matter and dark energy, that is. While dark matter is the strange substance that holds galaxies together, dark energy is the force that seems to be driving them apart, accelerating the expansion of the Universe. However, even though these dark cousins have been part of our understanding of the Universe for decades, we don't really know what they are.

Euclid will help astronomers understand these mysterious forces by surveying billions of galaxies, the light of which has taken over 10 billion years to reach us. Covering one third of the extragalactic sky beyond the Milky Way, astronomers will be able to use Euclid data to create a map of galaxies through cosmological time, showing how the Universe has expanded and grown. With this tool in hand, it is then possible to backtrack to gain an insight into how dark matter and energy shaped the cosmos around us.

Then, in the last quarter of the year, the Chinese space agency will launch **Xuntian** (meaning 'survey the heavens'). The telescope is similar to the aging Hubble Space Telescope in many ways – its mirror is two metres wide, it images in the visible and near-ultraviolet, and it is designed to be multipurpose – but its cameras have 300 times the resolution of its predecessor. Xuntian will fly in the same orbit, though separate from, the recently completed Tiangong Space Station, and will be able to dock for repairs and upgrades, meaning it could operate long past its initial decade lifespan.

Crew modules take off

Two new human-rated space vehicles take to the sky this year


Boeing's reusable Starliner capsule will carry astronauts to and from the ISS

Human spaceflight is entering a new era. In November 2022, NASA successfully tested its new Orion crew module that will take humans back to the Moon – and ultimately perhaps beyond. But that doesn't mean low-Earth orbit is being forgotten. The Roscosmos's Soyuz, the Chinese Shenzhou and SpaceX's Crew Dragon will continue ferrying astronauts to their respective space stations, but two more vehicles could be about to join their ranks.

In April, Boeing hopes to launch the first crewed test of its reusable **Starliner** space craft, to ensure the spacecraft is ready to begin ferrying astronauts to the International Space Station full time. The mission will have two experienced astronauts on board and will dock with the ISS for several days. The flight is years behind schedule after its first uncrewed test flight in 2019 failed to reach the correct orbit. After making more than 60 corrective actions, Boeing successfully repeated the test in May 2022 (despite two thrusters shutting down early), clearing the way for a crewed test.

Elsewhere, the Indian Space Research Organisation has been working on its own crew module, **Gaganyaan**, and hopes to complete at least one uncrewed test in the second half of 2023. If all goes to plan, the spacecraft will be cleared for a test flight with up to three crew members on board in 2024. If you want to get into low-Earth orbit next year, then you're certainly going to be spoilt for choice!

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor. Her book *Robots in Space* is available through History Press

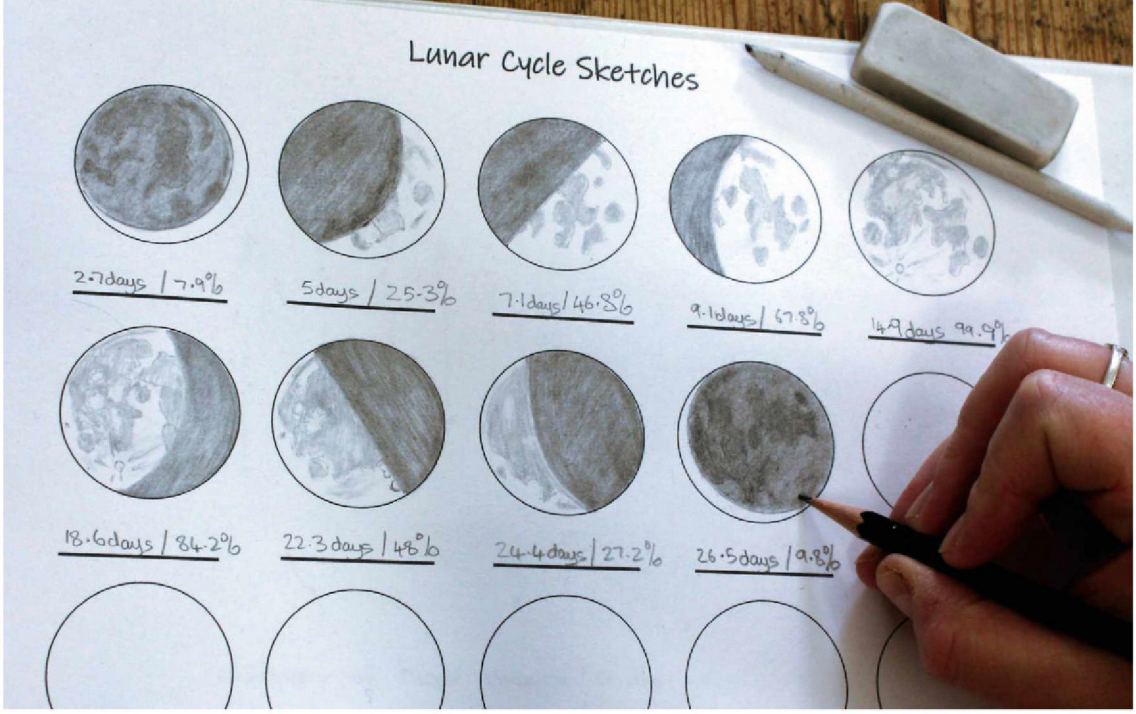
All together now: get the family off their devices and out sharing the wonders of the night sky

Family-friendly ASTRONOMY

Mary McIntyre reveals practical tips and fun projects that will get the whole family – young and old – looking up

Finding an activity that everyone in the family is happy to take part in can be challenging. If you've ever tried to arrange a family movie night, you'll be familiar with the struggle! One activity that you can easily do as a family is practical astronomy. You may have children of different ages, with teenagers hesitant to join in. You may have family members with mobility problems or those who think they're not interested in astronomy. Practical astronomy is fun and can be adapted to suit all needs and interests.

We're going to look at some stargazing activities that can be done all year round, but the winter months are ideal as it gets dark early, so young children won't need to stay up late. You don't need expensive equipment: just dress warmly, get yourself a red-light torch, a star chart or planisphere and find a place in your garden or local park where you're shielded from streetlights. There are also great night-sky apps to try; remember to turn your phone screen red and the brightness down, to help your night vision. Perhaps the best advice of all, though, is to take things at your own pace and have fun!



▲ A pencil and paper are all you need to get to know the phases of our Moon. Draw what you see as it waxes and wanes

1. Observe the Moon

▲ Get a real feel for the lunar surface with a 3D-printed model

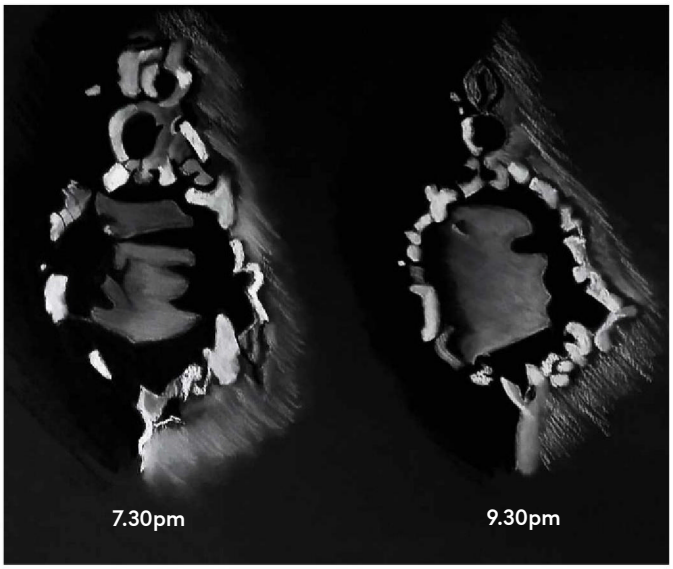
The Moon is a fantastic target for astronomers of all levels, and a great place to get started is by creating pencil sketches of it during an entire lunar cycle. How does it change day by day? What effect does the changing illumination have on the features?

Choose a time when the Moon is about half-illuminated – that's when its southern hemisphere craters are most distinct. Start by observing the Moon with the naked eye and make a note of the features you can see. Then look at it through binoculars: what can you see now that you couldn't see before? Finally, observe it with a telescope and different eyepieces. What does the telescope show you that binoculars didn't? You can research these features and how they formed.

People with visual impairment – and everyone else – can enjoy learning about the lunar landscape by using clay models made by a family member, or 3D-printed models. You can also use a torch on the model to try to mimic the shadow effects that you'll observe in the next activity.

Using a telescope and a high-power eyepiece, locate a lunar crater that has nice shadows around it; ones that fit the bill will be near to the boundary between the illuminated and unilluminated sides of the Moon (the 'terminator'). Note the time and make a sketch showing the shape and length of the shadows. Two hours later, observe the same crater and make another drawing. How have the shadows changed over the two-hour period?

If you have a maths whizz in the family, they could try measuring the width of the crater and the length of the shadows, then using those numbers to calculate the height of the crater wall. Find out how to do this online at **bit.ly/crater-height.** ▸

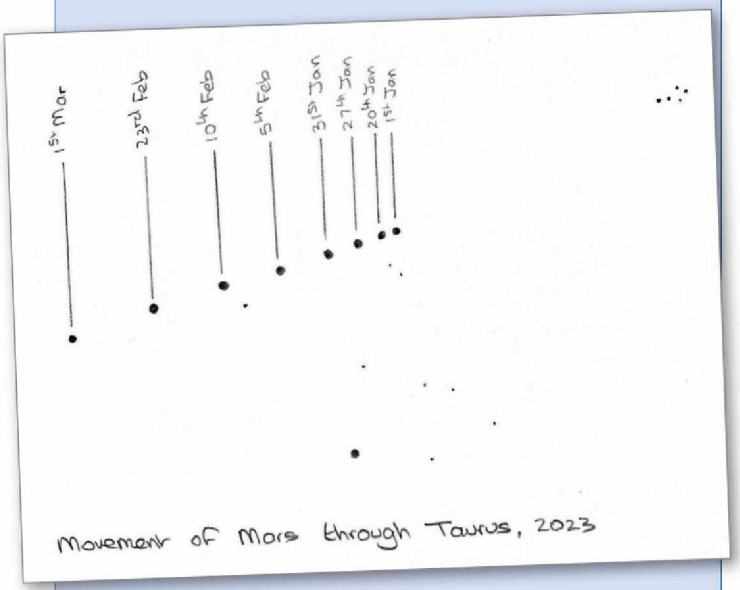


▲ Quick sketches will reveal how the Moon's crater shadows change

ANDRII BILETSKYI/ALAMY STOCK PHOTO, MARY MCINTYRE X 3

2. Track a bright planet through a constellation

The movement of planets is different from that of the stars, which is why they were historically called 'wandering stars'. It's great fun to track the movement of a planet against the background stars and you can do this with the naked eye or with binoculars. Try it during January and February when Mars is very well-placed in Taurus, having had its closest approach to Earth in December. Make a sketch of the stars in Taurus, then mark the location of Mars several times over a couple of months. Take note of how far it has moved between each observation and what direction it is moving in.



▲ Make a sketch of the stars in the constellation of Taurus and watch how Mars moves through the scene in the coming weeks

A favourite star and a bit of maths will prove Earth's spin takes less than 24 hours

3. How long does it take for Earth to make one rotation?

Earth takes 24 hours to complete one rotation, right? It actually takes slightly less than that. You can test out how much less by studying the movement of the stars. Position yourself so you can see a bright star disappear behind a chimney pot. Note the exact time it vanishes. Repeat this with the same star, from the same position, over the next few nights, noting how many minutes difference there is. After a week, you'll have six values. Add them, divide the total by six to get the average, and convert them to seconds. Watching Vega we saw a difference of four minutes and five seconds (245 seconds). The published figure is three minutes 56 seconds (236 seconds) short of 24 hours: that's one rotation every 23 hours, 56 minutes and four seconds. What do you get?

4. Mobility problems? Binocular solutions

Visual astronomy with a telescope can be challenging for people with mobility issues, but binoculars are a brilliant alternative. Small binoculars have the advantage of being lightweight so they can be hand-held. If you have larger, heavier binoculars, mounting them can make all the difference. A simple tripod mount works well when viewing objects that are lower in the sky, and you can straddle the tripod legs around a stool or wheelchair. If you're viewing objects that are higher, a parallelogram mount is a better option because they allow much easier access to the eyepiece from a seated or standing position.

A tripod can straddle your chair to support heavier binoculars

MARY MCINTYRE X 2, STEVE MARSH X 2, SAVOILIC/ISTOCK, GETTY IMAGES

5. Get the whole family using a telescope

Do you have a telescope? Has the whole family had a go yet? A few practical tips will help you to get the most out of your first family observing session.

Ergonomics are important. If you're not comfortable when looking through an eyepiece, your body will quickly feel fatigued. Set the tripod to the correct height for the observer. If you have a refractor, rotate the barrel so the eyepiece is in the right position for family members of different heights. Consider a perching stool for comfort and back support. For a reflector, have younger children stand on stepstools to look through the eyepiece; they won't be able to observe properly if they're being carried.

Scrunching one eye closed while observing with the other is not comfortable and your facial muscles will quickly become tired. A better technique, especially for children who sometimes struggle to close only one eye at a time, is to keep both eyes open but cover one with your hand. You can also buy astronomers' eye patches for this purpose and enjoy looking like a pirate astronomer!

Beginners may feel underwhelmed the first time they observe an object visually compared to the amazing long-exposure photographs we see, so it is important to manage expectations. Knowledge about the distance the light has travelled from the object to their eye, as well as other basic facts about the object, can help everyone to feel that important visual connection. The longer you look at something through an eyepiece the more faint detail you will see, so encourage people to spend a long time observing each object. This is also an opportunity to use averted vision, a technique of looking off to one side of a faint object so that it will appear to brighten in your peripheral vision. ▸

Provide a stool so younger children can reach the eyepiece easily

Teach youngsters to cover one eye to make observing more comfortable

6. See the far-distant Andromeda Galaxy with your naked eye

At 2.5 million lightyears away, the Andromeda Galaxy, M31 is the most distant naked-eye object. You'll need a relatively dark, moonless night and dark-adapted eyes to see it: around 7pm during mid-January is a great time to try. Locate the star Mirach in the constellation of Andromeda and then Schedar, the bottom star on the right-hand side of the 'W' of Cassiopeia. Draw an imaginary line between the two. The Andromeda Galaxy lies about a third of the way along from Mirach and slightly below the line. You may need averted vision to see the faint smudge. How does it appear through binoculars or a telescope?

▲ Trace a line from Andromeda's 'hip' star, Mirach, up to Schedar to locate M31, the most distant thing you can see with your naked eye

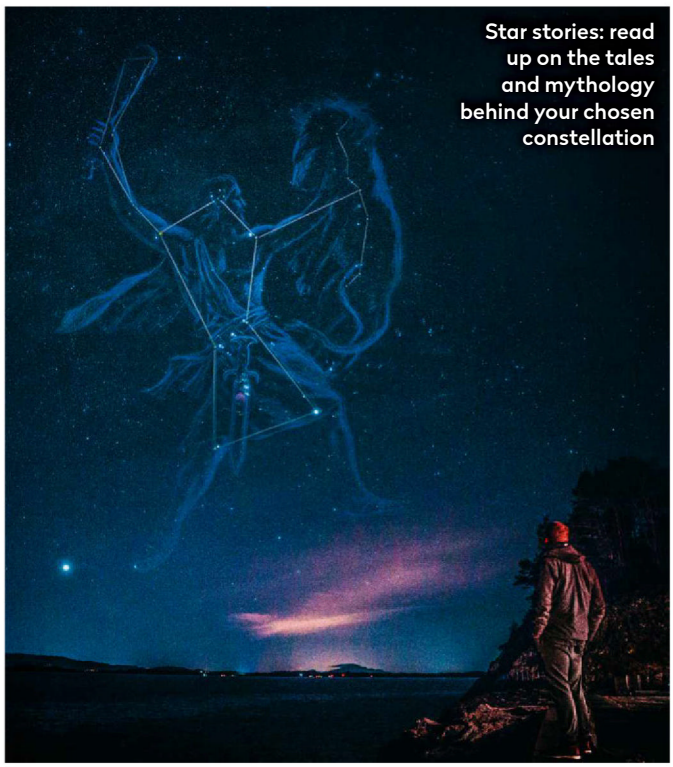
7. Take a deep dive into a constellation

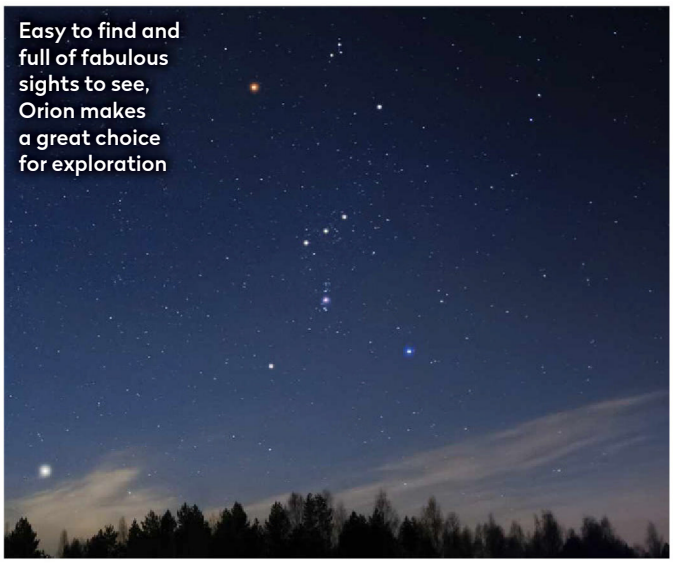
This activity is great because you can keep it simple or get quite complex. Choose any constellation: Orion is a great choice during the winter because it is full of interesting sights and easy to spot.

Research your constellation's Greek mythology. Do the star patterns look like the character or object? How does it compare to mythologies from other cultures? What do *you* think it looks like? Draw your own character and write a story about them.

On a moonless night, count how many stars you can see in the constellation when you first go out, before your eyes have adapted to the darkness. Repeat after 15 and 30 minutes outside. How many more stars can you see? Are they different colours? Try again under a bright Moon. Does this affect your count? You can even then try with the constellations that lie adjacent to it.

Sketch your constellation, paying attention to the stars' spacing and magnitude (brightness) differences. Drawing makes you a better observer, so encourage everybody to try! Take a photo of your constellation using a smartphone camera and app such as NightCap, or with a DSLR camera. Are there more stars in the photo compared to what you see?


Star stories: read up on the tales and mythology behind your chosen constellation


Easy to find and full of fabulous sights to see, Orion makes a great choice for exploration

Use a star chart and choose some deep-sky objects in your constellation and see if you can find them using binoculars or a telescope, learning how to get to them by star-hopping.

If you want to get complex, use theory to work out a star's absolute magnitude. First find the apparent magnitudes of nearby stars (how bright they look from Earth) and use them to estimate the apparent magnitude (m) of the stars in your constellation. The absolute magnitude (M) is how bright the stars would look if they were all 10 parsecs away. Look up the distances (d) to the stars in your constellation (in parsecs) and combine these with the apparent magnitudes to calculate the absolute magnitude from those figures, using the following formula: **M = m + 5 – 5 log d**

CHART BY PETE LAWRENCE. EERIK/ISTOCK/GETTY IMAGES, LARS EMIL AGA HAUGOM/ ALAMY STOCK PHOTO, PAUL WHITFIELD, SKYSAFARI, ISS DETECTOR, PHILIPS

8. Connect a camera to your telescope

People with mobility problems or some visual impairment may physically struggle to look through a telescope eyepiece. A solution is to attach a camera to your telescope and display the view on a laptop. If using a smartphone camera, try apps such as DroidCam (Android and iOS) or EpocCam (iOS). DSLR users can use Backyard EOS, Backyard Nikon or DeepSkyStacker Live, while CCD or CMOS users can use SharpCap or FireCapture. Now everybody can share the view at the same time. Some software even offers a live stacking option that will slowly build up a more detailed view of the object, live on screen.

Display and share your telescope view on a laptop for everyone to enjoy

9. Use remote access

Family members who are housebound may feel they miss out on visual astronomy, but remote access technology can bring a telescope view inside. Connect your camera and telescope as described above and, as long as the laptop displaying the telescope view is connected to your home network, you can use RealVNC (downloads available for PC or Mac) or Windows Remote Desktop software to connect an indoor computer to the screen outside. This means those inside can still enjoy visual astronomy with the rest of the family. If the telescope is controlled by planetarium software, the person indoors can have complete control from inside the house.

10. Keep up to date with the night sky

There are always interesting things to spot in the night sky. *BBC Sky at Night Magazine* has a full roundup of what's coming up each month, and there are many books that show you events to look out for throughout the year. Great options are the Philip's *Stargazing* and *Collins Night Sky* guide books. Try your local library or secondhand book shop. There are also countless websites, newsletters and smartphone apps such as Stellarium and SkySafari that will inform you of the best constellations, meteor showers, planets and deep-sky objects to observe from your location. Lunescope is a fantastic lunar observing app. If you enjoy spotting the International Space Station and other satellites, use the Heavens Above website or the ISS Detector smartphone app. There is something that every family member will enjoy!

Mary McIntyre is an Oxfordshire-based astronomy speaker and educator

◂ **A host of astronomical resources are out there to help, from magazines and books to apps like SkySafari and ISS Detector**

COSMOLOGY CRASH COURSE

Redshift, the change that light undergoes on its journey from distant galaxies, is a key tool for measuring the Universe

Why are galaxies redshifted?

In Part One of our new cosmology course, we examine why it is that galaxies look redder the further away they are

Since the launch of the James Webb Space Telescope, there has been renewed interest in the most distant galaxies in the Universe, those with the highest 'redshift'. Redshift is a term readers of *BBC Sky at Night Magazine* will have encountered before, but what exactly is it? Why are galaxies redshifted? And how is redshift a measure of distance?

Redshift is precisely what the name implies. Light is comprised of waves, the wavelength of which determines their colour. The light of remote galaxies we observe with our telescopes has a slightly redder colour than the light emitted by that galaxy long ago – the wavelengths have shifted towards the red end of the spectrum. But why does this happen?

More often than not, this redshift is erroneously explained as a Doppler effect, where the motion of an object changes the wavelength it emits. If it is moving away, then each new wave crest is emitted from a slightly larger distance away from the observer, so each subsequent wave crest takes longer to arrive, corresponding to a longer observed wavelength. For sound waves, this would mean a lower pitch; for light, a redder colour. In the case of an approaching light source, we observe a shorter wavelength (a higher pitch or 'blueshift'). The faster an object is moving towards or away from the observer, the larger the shift will be.

Govert Schilling's book *The Elephant in the Universe* is published by Harvard University Press

This phenomenon was predicted in 1842 by Austrian physicist Christian Doppler. In 1845, the Doppler effect was first demonstrated for sound, in a famous experiment in which Dutch meteorologist Christophorus Buys Ballot put horn players on a moving train. Observers on the platform heard the changing pitch – higher as the train approached, lower as it sped away.

Making waves

Three years later, French physicist Armand Hippolyte Fizeau observed Doppler shift in the light of stars. Using spectral features – bright lines that appear at specific wavelengths – he could tell how much its observed wavelength had shifted, revealing the star's velocity along the line of sight: its radial velocity.

The number game

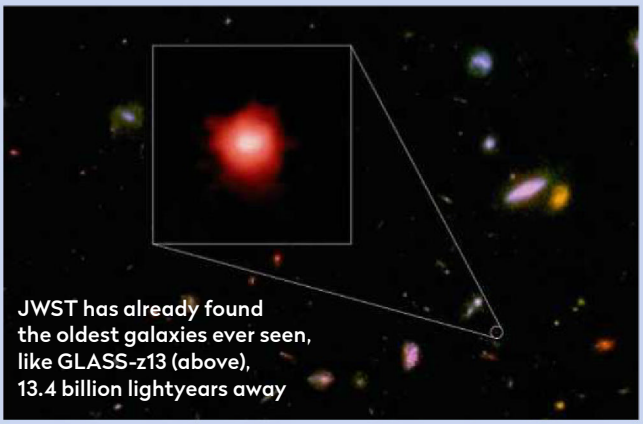
Astronomers describe the redshift of light (denoted by z) using the percentage its wavelength has changed. For example, if a galaxy's visible light, emitted at a wavelength of 500 nanometres (nm), arrives at Earth at 700nm, it has been redshifted by 200nm. That's a change of 40 per cent from the original, so its redshift is z = 0.4.

James Webb's infrared view

Powerful telescopes can be used as time machines to the early Universe

The further out into space you look, the further back in time you are seeing. The most remote galaxies ever observed are so far away that their light – even though it moves at the incredible speed of 300,000km per second – has taken more than 13 billion years to reach Earth, meaning we are seeing them as they were in the childhood days of the Universe.

Back then, the very first stars emitted copious amounts of energetic ultraviolet light, at typical wavelengths of a few hundred nanometres. But thanks to the long light travel time and the corresponding large cosmological redshift, these high-energy light waves get redshifted all the way into the infrared part of the spectrum, at wavelengths of a few micrometres. That's one of the reasons why the James Webb Space Telescope is outfitted with infrared cameras and spectrometers – it's the only way to study the most distant and earliest galaxies in the Universe.

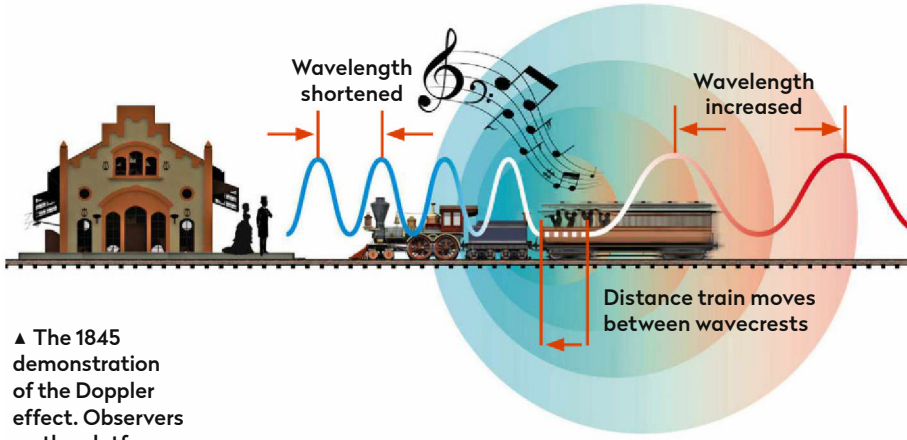


JWST has already found the oldest galaxies ever seen, like GLASS-z13 (above), 13.4 billion lightyears away

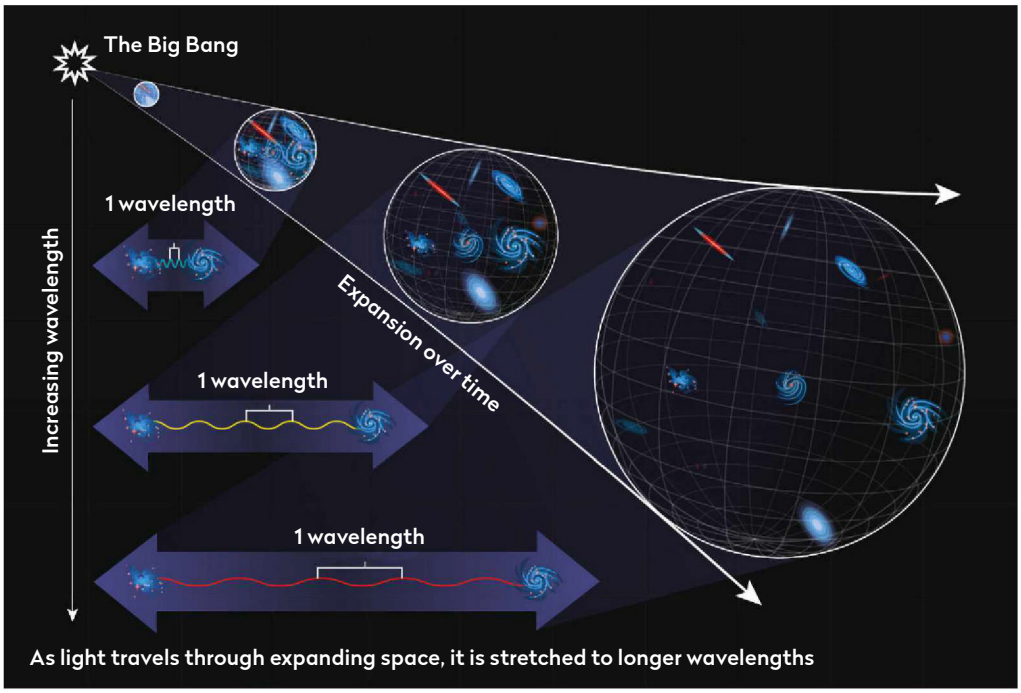
Observing redshift on larger scales, however, didn't occur until 1912, when Lowell Observatory astronomer Vesto Slipher found that most galaxies displayed large redshifts, meaning they were receding at hundreds or even thousands of kilometres per second. But the discovery of the expansion of the Universe, by Belgian cosmologist Georges Lemaître and his American colleague Edwin Hubble in the 1920s, turned everything on its head.

The thing is: galaxies are not racing through stationary space, as many people believe. Instead, empty space itself is expanding, pushing galaxies ever further apart. If there's no true space motion, the Doppler effect doesn't come into play.

So why are galaxies redshifted? Well, think of light waves with a particular wavelength emitted by a remote galaxy. It may take many millions of years for these light waves to reach Earth. During this time empty space is expanding, stretching the light waves along with it, so they arrive at Earth with a longer, redder wavelength. This type of redshift is called the cosmological redshift.



▲ The 1845 demonstration of the Doppler effect. Observers on the platform heard the music at a higher pitch as the sound wavelengths decreased



As light travels through expanding space, it is stretched to longer wavelengths

And here's the relation between distance and redshift: the further away a galaxy is, the longer its light takes to reach us. A longer light travel time means more cosmic expansion, more wavelength stretching and thus a higher redshift. Doppler shift from the galaxy's motion through space may slightly adjust this cosmological redshift, but this is a minor effect for remote objects, so a galaxy's observed redshift is usually a reliable indicator of its distance.

So forget the idea of galaxies speeding away from each other through space, and instead remember that space itself is expanding, continuously stretching light waves that propagate through it.

NASA/ESA/J. DALCANTON (UNIVERSITY OF WASHINGTON)/R. FOLEY (UNIVERSITY OF CALIFORNIA SANTA CRUZ), NAIDU ET AL. 2022/CASTELLANO ET AL. 2022, JOSE ANTONIO PEÑAS/SCIENCE PHOTO LIBRARY, NASA/ESA/ESA/LEAH HUSTAK (STSCI)

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BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

JANUARY 2023

MARS CHANGES COURSE

The Red Planet's apparent motion against the stars reaches a pause this month

URANUS DISAPPEARS

UK viewers see planet occulted by the Moon on New Year's Day

COMET BRIGHTENING

C/2022 E3 ZTF swings into view

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Moon, Venus and Saturn together
- Deep-sky targets north of Lepus, the Hare
- Our challenge: hunt down the reddest star

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

JANUARY HIGHLIGHTS

Your guide to the night sky this month

◀ Sunday 1

The 77%-lit waxing gibbous Moon occults Uranus from around 22:00 UT until 23:30 UT from northern areas of the UK. See page 47 for more details.

Monday 2

Minor planet 2 Pallas is at opposition, unfavourably positioned at mag. +7.8 in the southern regions of Canis Major.

Wednesday ▶ 4

The Quadrantid meteor shower peak is expected around 04:00 UT. A 92%-lit waxing gibbous Moon will interfere.

Earth is at perihelion today, orbitally at its closest position to the Sun.

Sunday 8

Thanks to lunar libration, the Moon's southern polar region is tilted favourably towards Earth – a good time to investigate this crater-heavy region of the Moon.

Thursday ▶ 12

Mars reaches a stationary point in the sky. Before this its motion was retrograde, the planet moving west against the background stars. After this date its apparent motion will be prograde, moving east.

Sunday 15

Comet C/2022 E3 ZTF is expected to reach mag. +6.3, and tonight into tomorrow morning is located just west of mag. +4.6 Chi (χ) Herculis.

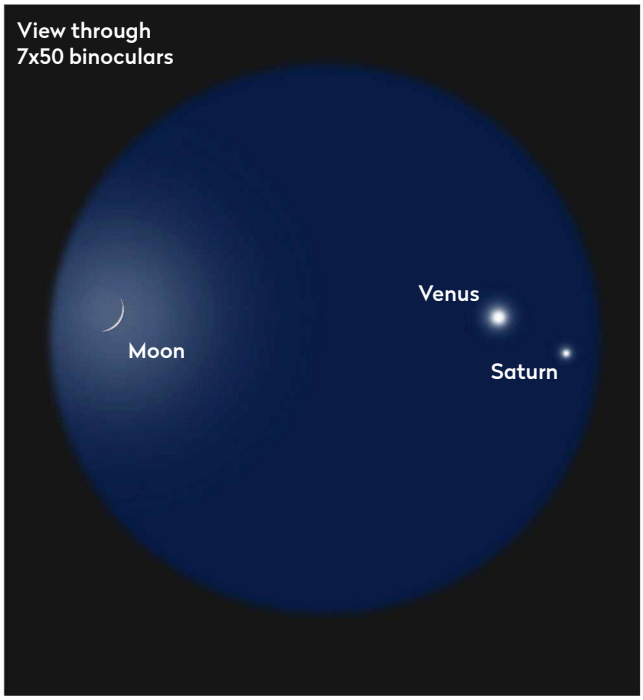
Sunday 22

Venus and Saturn appear separated by 23 arcminutes this evening. They are closest just before they set at around 18:30 UT.

Monday ▶ 23

A thin, 5%-lit waxing Moon joins Venus and Saturn in this evening's sky after sunset.

Mag. +5.6 comet C/2022 E3 ZTF is currently near mag. +3.3 star Iota (ι) Draconis.



Family stargazing

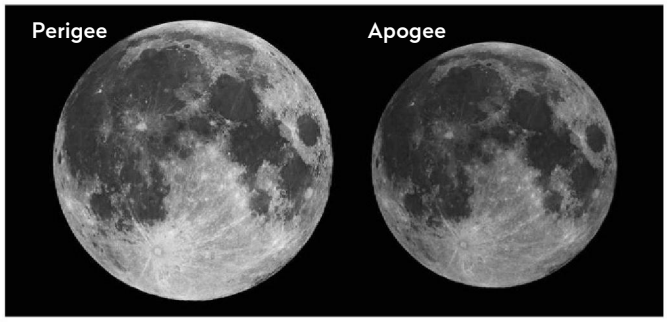
There is an exciting opportunity to find comet C/2022 E3 ZTF at the end of this month, when the comet could potentially be a faint naked-eye object passing close to the stars Kochab, Pherkad and then Polaris in Ursa Minor, the Little Bear. To find it, use our chart on **page 46.** Although it may be visible with the naked eye, binoculars are probably a better way to spot it. Look for a fuzzy smudge of light, and if you are successful in finding it, explain that this 'dirty snowball' is on an open orbit and won't be seen again after this pass!
bbc.co.uk/cbeebies/shows/stargazing

PETE LAWRENCE X 6, STOCKTREK IMAGES, INC./ALAMY STOCK PHOTO

Tuesday ▶ 3

At around 03:30 UT this morning, the 86%-lit waxing gibbous Moon sits 3.1° south of the Pleiades.

This evening, around 19:16 UT, mag. –1.2 Mars is 1.1° north of the 91%-lit waxing gibbous Moon.

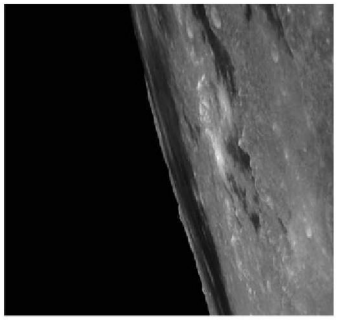


◀ Friday 6

This evening's full Moon occurs near lunar apogee, when it is furthest from Earth in its orbit. Appearing subtly dimmer and smaller than an average full Moon, this is informally known as a 'micromoon'.

Wednesday ▶ 18

The waning crescent Moon's western libration region is tilted towards us. This gives us a better view of the Mare Orientale region, among others.



Friday 20

The gas giant Jupiter reaches perihelion, the closest point to the Sun in its orbit. Today, it will be 4.95101 AU from the Sun.

Tuesday 24

This morning comet C/2022 E3 ZTF is expected to be at mag. +5.6 and passing a couple of degrees east of the mag. +9.9 galaxy M102 in Draco.

Wednesday 25

A lovely encounter between this evening's 21%-lit waxing crescent Moon and bright Jupiter can be seen over towards the southwest as the sky darkens.

Friday 27

Comet C/2022 E3 ZTF is close to Kochab (Beta (β) Ursae Minoris) this evening and into tomorrow morning.

Sunday 29

Comet C/2022 E3 ZTF is expected to be around mag. +4.9 at present. It is currently close to Polaris, which makes it especially easy to locate. See page 46 to find out more.

Monday 30

Mercury is at greatest western elongation, separated from the Sun by 25° in the morning sky.

A 64%-lit waxing gibbous Moon is 5° from the Pleiades just before setting this morning.

Tuesday 31

Bright Mars shines at mag. –0.3 and sits just 1° from the 73%-lit waxing gibbous Moon at 04:15 UT, as the pair approach the northwest horizon when they're setting.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

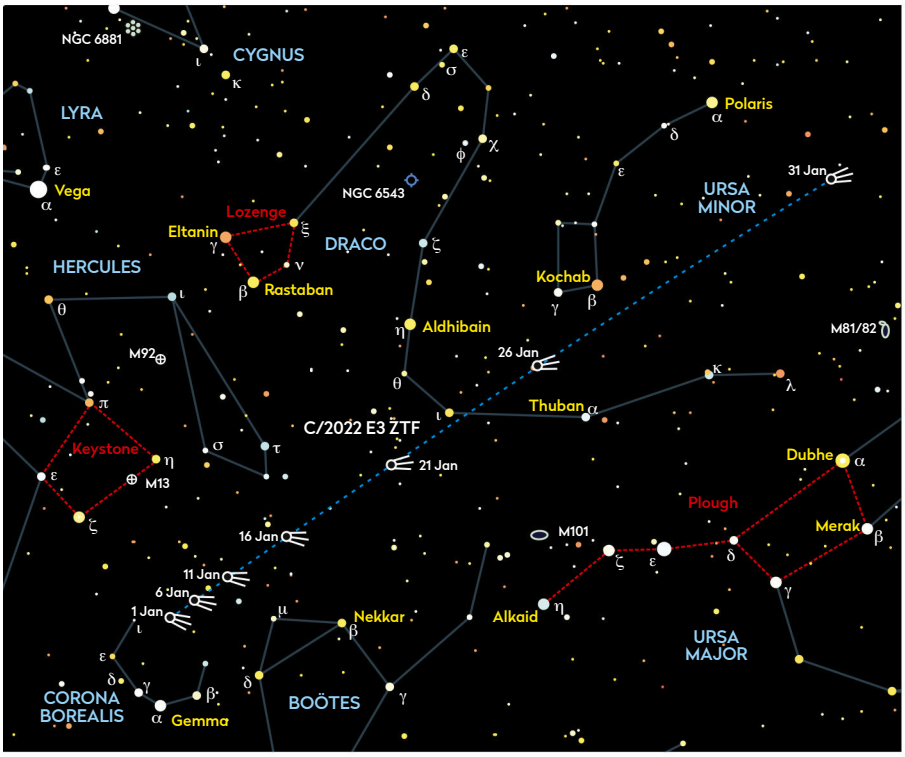
Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

Comet C/2022 E3 ZTF brightens

BEST TIME TO SEE: Last week of January



◂ **C/2022 E3 ZTF heads north throughout the month, brightening as it goes**

Comet C/2022 E3 ZTF makes a dash for it this month. Having held position in the region of Corona Borealis over the past weeks, the comet rapidly heads north during January. C/2022 E3 ZTF begins the month at a predicted magnitude of +7.5.

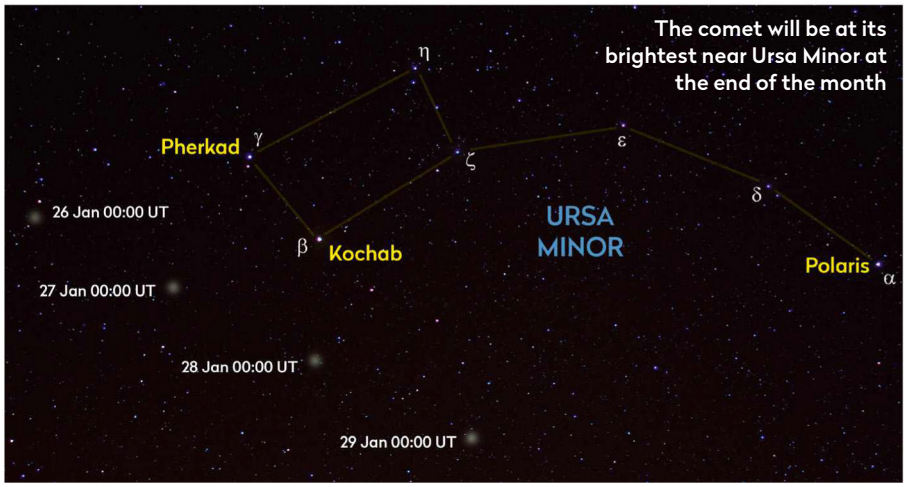
On the nights of 10/11 and 11/12 January, it is expected to have brightened to mag. +6.8 and will be approximately 5° east of Alkalurops (Mu (μ) Bootis). It formally exits the border of Corona Borealis on 13 January, continuing its northerly track. It then sits 5° west of mag. +3.9 Tau (τ) and +4.2 Phi (φ) Herculis on 17/18 January.

After this date, if it follows its predicted brightness curve, the comet will pass the naked-eye threshold, mag. +6.0. Appearing as a diffuse, fuzzy object, this brightness is an integrated magnitude: how bright the comet would appear if all its light were concentrated into a single point of light, like a star. So despite passing the threshold, it is unlikely to be a naked-eye object at this time.

Despite this, it should be a relatively easy binocular object and will hopefully continue to brighten over the coming days. Passing 2° east of the mag. +9.9 galaxy M102 on the night 22/23 January, the comet is predicted to be at mag. +5.6. Continuing north-northwest, it passes 1° west of mag. +3.3 Iota (ι) Draconis on the night of 23/24 January. On the night of 25/26 January it will have crossed the border into the most northerly constellation of them all, Ursa Minor, the Little Bear. As it does so it passes less than 0.5° west of the variable star RR Ursae Minoris, a red star that varies in brightness between mag. +4.5 and +4.7.

C/2022 E3 ZTF lies a little over 3.1° from Kochab (Beta (β) Ursae Minoris) on the night of 27/28 January, a location that should make it fairly easy to find, given that it will be possible to place both objects in the field of view of average binoculars. The Moon will be a 42%-lit waxing crescent on 27 January, so wait for it to set before making your attempt. On this date, as long as it behaves – and there is no guarantee with a comet – C/2022 E3 ZTF should be shining with an integrated magnitude of +5.0 and, possibly, visible to the naked eye given a dark sky.

At the end of the month it will have passed into the faint constellation of Camelopardalis as it begins a rapid dive southwest through next month.



ALL PICTURES: PETE LAWRENCE

Lunar occultation of Uranus

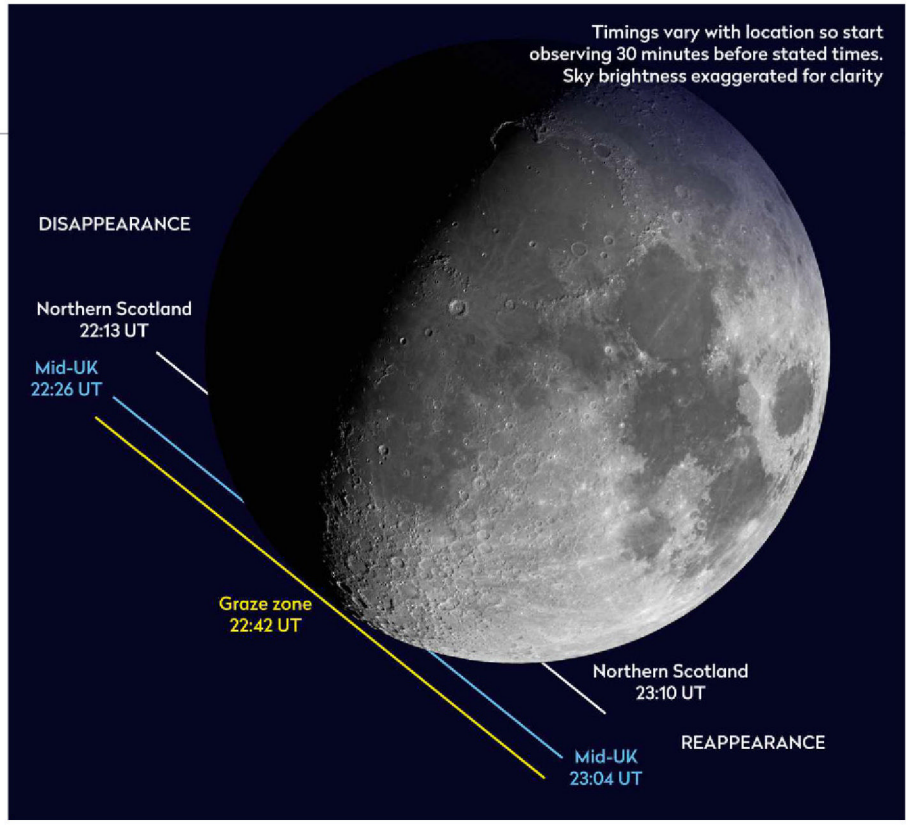
BEST TIME TO SEE: 1 January, from 21:45 UT until 23:40 UT

The Moon passes in front of Uranus late in the evening on New Year's Day. It is difficult to give precise timings because location makes a big difference with this occultation. It is the southern edge of the Moon that occults the planet and, depending on where you live in the UK, you will either see a near-miss, a grazing occultation or a full occultation.

The transition or graze line between near-miss and full occultation runs from Pembroke in south Wales, through the Midlands and East Anglia, leaving the east coast near Lowestoft. Anywhere south of this line sees a near-miss; those further north see a full occultation. The deepest occultation will be seen from northern Scotland, with disappearance at 22:13 UT and reappearance at 23:10 UT. For those in the middle of the UK, the event runs from 22:26 UT to 23:04 UT, but as you get closer to the transition zone the time difference between disappearance and reappearance narrows. From the graze zone, Uranus will appear clipped by the Moon's southern edge at 22:42 UT, but as ever we recommend watching from 20–30 minutes earlier so you don't miss anything.

If you happen to be on the graze line, you may be lucky enough to see a grazing occultation, where the planet dips in and out of visibility as it passes behind lumps and bumps on the Moon's southern limb. From some locations Uranus may only partially disappear.

Although a telescope will give a view of the Moon with Uranus as a disc, binoculars can also be used, where mag. +5.7 Uranus appears just like a dim star hidden – or nearly hidden depending where you live – by the Moon.



▲ **The lunar occultation of Uranus on the evening of 1 January will be experienced in different ways and at slightly different times depending on your location within the UK**

Venus meets Saturn

BEST TIME TO SEE: 20–25 January, an hour after sunset

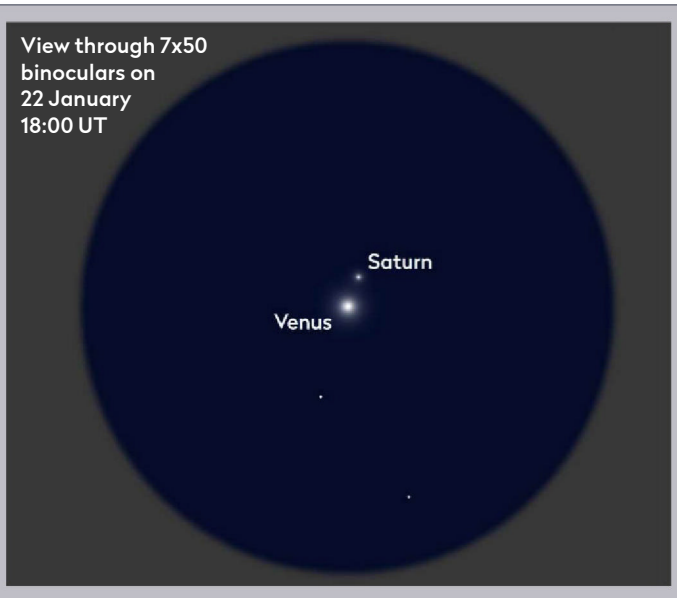
Venus is returning to the evening sky and can be found close to the considerably dimmer planet Saturn towards the end of the month. Saturn's observing window is closing as it appears closer to the Sun, but with the naked eye and some clear skies it can still be seen at the end of January just as the skies start to darken in the evenings.

The best time to start looking is 20 January. Approximately one hour after sunset, look for Venus 6° above the southwest horizon. Although low, mag. –3.8 Venus should be easily visible. Saturn appears 2.5° above and left of Venus as seen from the UK.

On 21 January, the gap closes to 1.4°, with Venus appearing a little higher than it did on 20 January, now 7° above the southwest horizon after sunset.

The evening of 22 January has the real treat. If skies are clear, Venus and Saturn will appear just 24 arcminutes apart. At this time mag. –3.8 Venus shines 70x brighter than mag. +0.8 Saturn.

On the evening of 23 January, although separating to appear 59 arcminutes apart, a 5%-lit waning crescent Moon appears 5.1° to the left of Venus as seen from the UK. Given clear skies, this is a definite invitation for a photo!



▲ **Venus appears very close to Saturn towards the end of the month**

THE PLANETS

Our celestial neighbourhood in January

PICK OF THE MONTH

Mars

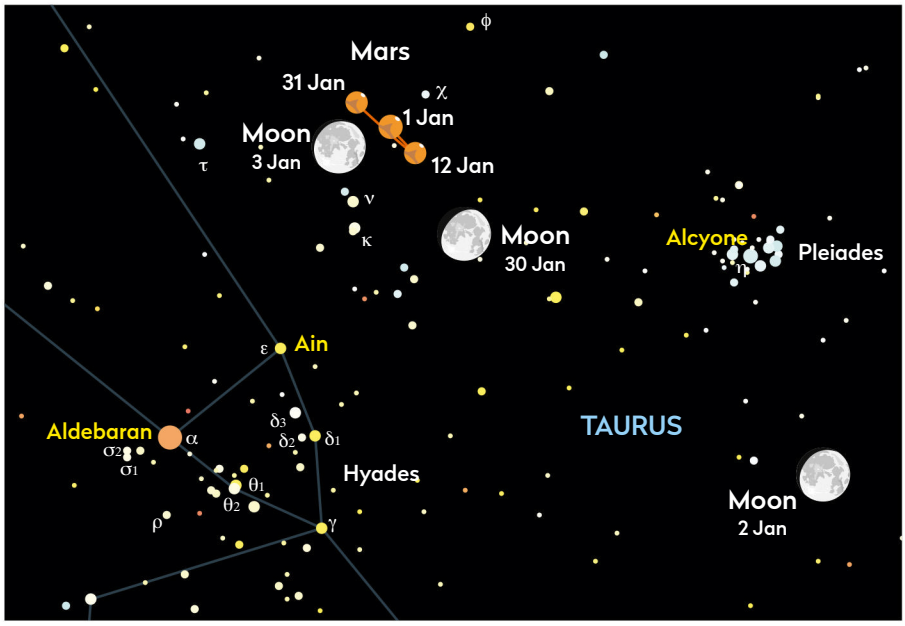
Best time to see: 1 January, 21:54 UT
Altitude: 62°
Location: Taurus
Direction: South
Features: Albedo markings, polar caps, weather
Recommended equipment: 75mm or larger

Mars was at opposition on 8 December 2022 and remains bright, prominent and beautiful to observe through a telescope. However, things are changing and not for the better. Mars is currently in Taurus, shining at mag. –1.2 on 1 January, a bright orange beacon to the west of the Pleiades open star cluster.

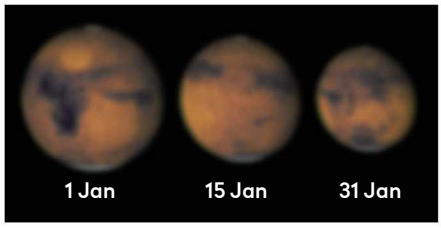
Through the eyepiece it shows a 14-arcsecond disc and detail should be easily discernible through a 150mm or larger instrument at high powers. It has a close encounter with a 91%-lit waxing Moon on the evening of 3 January, both objects appearing just 1.6° apart (centre-to-centre) at 19:15 UT. After its closest approach to Earth on 1 December, Mars is now moving away, evidenced by a drop in brightness to mag. –0.7 on 15 January, showing an apparent size of 12 arcseconds. By 31 January, Mars shines at mag. –0.3 and appears 10 arcseconds across through the eyepiece.

The bright orange dot of Mars is easy to see and its colour is obvious to the naked eye. It appears to move west against the distinctive stars of Taurus for the first week of January but this motion then becomes slow and hard to detect. On 12 January the geometry of both Earth and Mars's orbits make it look as if the Red Planet reverses direction. After this 'stationary point' Mars begins to head east among the stars once again. A westerly direction is referred to as retrograde, easterly prograde.

This opposition of Mars has presented the planet to us sideways-on, with both polar regions visible. We should now see the large north polar hood (NPH) which shrouds the northern cap, start to break up, finally revealing the cap itself.



▲ **Around 12 January, Mars appears to stop then change direction to begin travelling east**

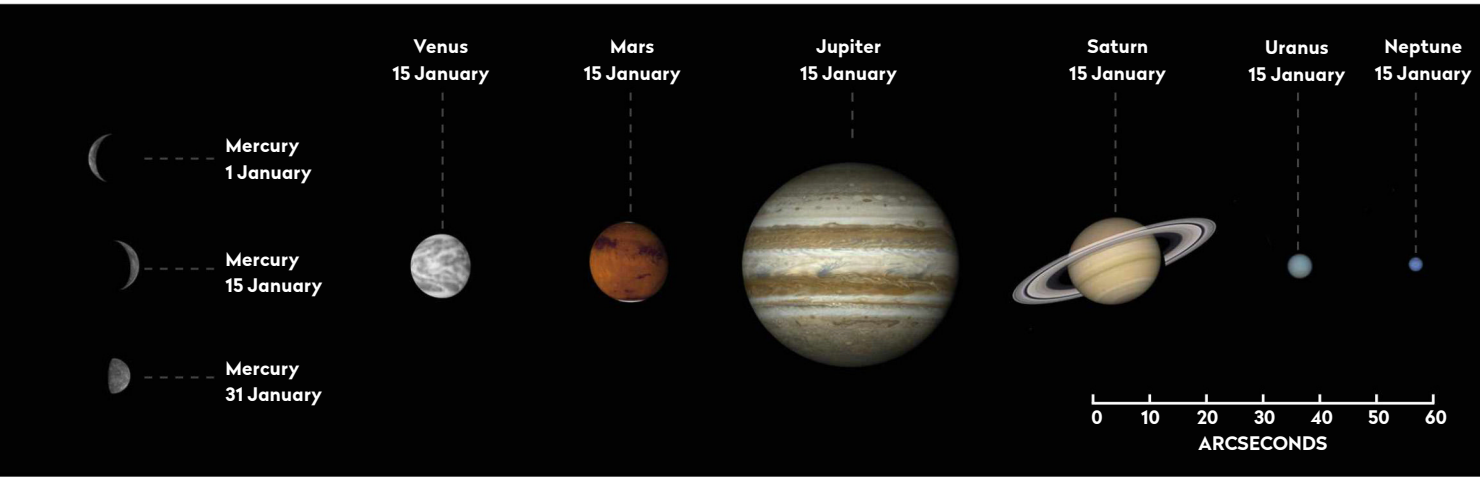


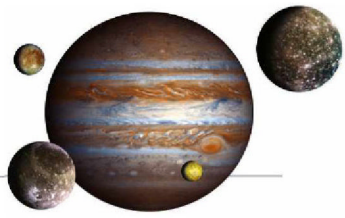
▲ **Changes in the relative apparent size of Mars as it moves away this month**

PETE LAWRENCE X 2

The planets in January

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 31 January, 40 minutes before sunrise
Altitude: 3.4° (very low)
Location: Sagittarius
Direction: Southeast

Starts the month not far from bright Venus in the evening sky, but at mag. +1.6 on 1 January and dimming thereafter, Mercury is difficult to spot in the evening twilight. Inferior conjunction is on 7 January, with Mercury a morning object thereafter. On 19 January it will be at mag. +0.5 with a slender 9%-lit waning crescent Moon 16° to the right as seen from the UK. Greatest western elongation on 30 January sees the planet 25° west of the Sun. It shines at mag. 0.0, rising 1.5 hours before sunrise on this date, visible low above the southeast horizon.

Venus

Best time to see: 31 January, 40 minutes after sunset
Altitude: 12°
Location: Aquarius
Direction: Southwest

A brilliant mag. –3.8 evening planet. On 1 January it is 5.6° from mag. +1.6 Mercury, setting 80 minutes after the Sun. Venus is close to Saturn on 22 January, the two worlds just 26 arcminutes apart at sunset. Saturn will be harder to see at mag. +0.8. On the following evening, the pair now appear separated by just under 1°, with a beautiful 5%-lit waxing crescent Moon 5° to the southeast. By the end of the month, Venus sets 135 minutes after sunset.

Jupiter

Best time to see:
1 January, 17:30 UT
Altitude: 36°
Location: Pisces
Direction: South

Jupiter is best at the start of January, thereafter losing altitude as darkness falls. A waxing crescent Moon sits nearby on evenings of 25 and 26 January, mag. –2.1 Jupiter forming a striking sight with the Moon's crescent.

Saturn

Best time to see:
1 January, 17:30 UT
Altitude: 15°
Location: Capricornus
Direction: Southwest

Evening planet not well-placed. At mag. +0.8, Saturn is joined by mag. –3.8 Venus on 21 and 22 January. By 31 January, the observational window for Saturn draws to a close.

Uranus

Best time to see:
1 January, 20:18 UT
Altitude: 53°
Location: Aries
Direction: South

Well-placed evening planet on the naked-eye threshold from a dark site. On 1 January at 22:30 UT, Uranus experiences a shallow occultation by the Moon's southern edge, an event heavily influenced by location (see page 47). Uranus is visible under dark sky conditions at its highest point, due south, most of the month.

Neptune

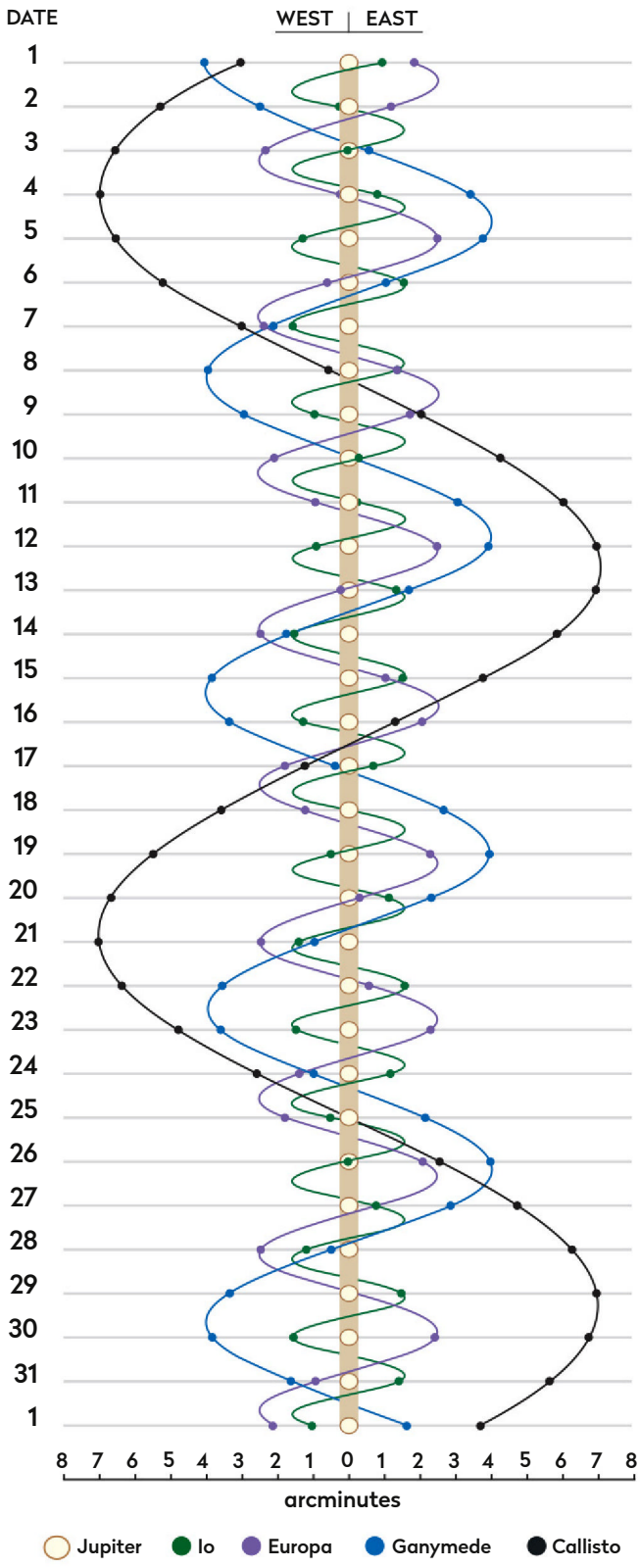
Best time to see:
1 January, 20:18 UT
Altitude: 31°
Location: Aquarius
Direction: South-southwest

Mag +7.9 Neptune is 8° west of mag –2.1 Jupiter on 1 January, this separation increasing to 12° by the month's end. A 20%-lit waxing crescent Moon sits between Jupiter and Neptune on the evening of 25 January, slightly south of the imaginary line between both planets.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: JANUARY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – JANUARY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Cricket — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

CHART: PETE LAWRENCE

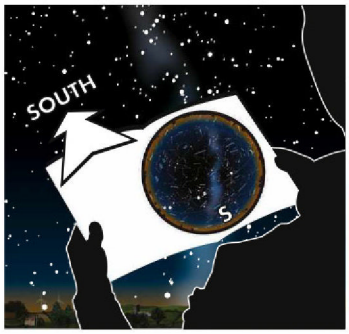
When to use this chart

1 January at 00:00 UT
15 January at 23:00 UT
31 January at 22:00 UT

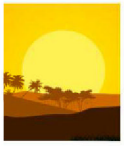
On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.



Sunrise/sunset in January*



Date	Sunrise	Sunset
1 Jan 2023	08:26 UT	16:01 UT
11 Jan 2023	08:21 UT	16:15 UT
21 Jan 2023	08:12 UT	16:31 UT
31 Jan 2023	07:57 UT	16:50 UT

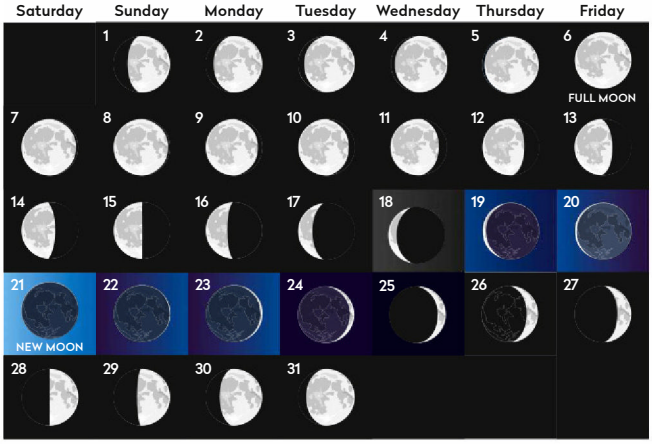
Moonrise in January*

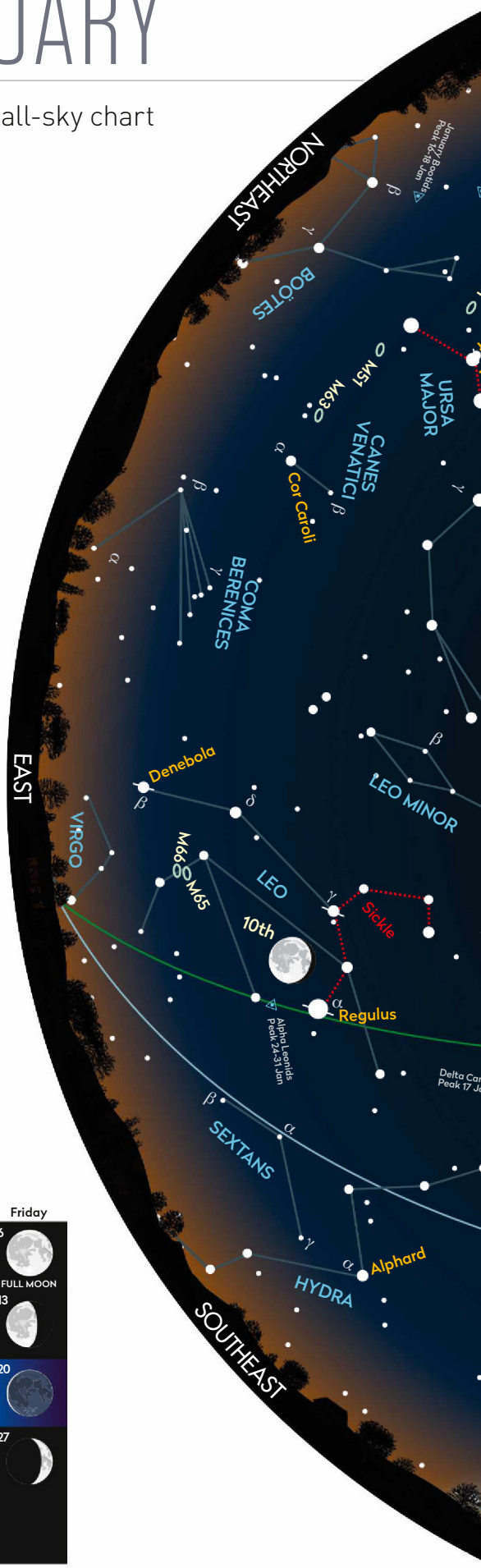
Moonrise times

1 Jan 2023, 12:36 UT	17 Jan 2023, 03:35 UT
5 Jan 2023, 14:16 UT	21 Jan 2023, 08:41 UT
9 Jan 2023, 18:35 UT	25 Jan 2023, 10:09 UT
13 Jan 2023, 23:31 UT	29 Jan 2023, 10:56 UT

*Times correct for the centre of the UK

Lunar phases in January





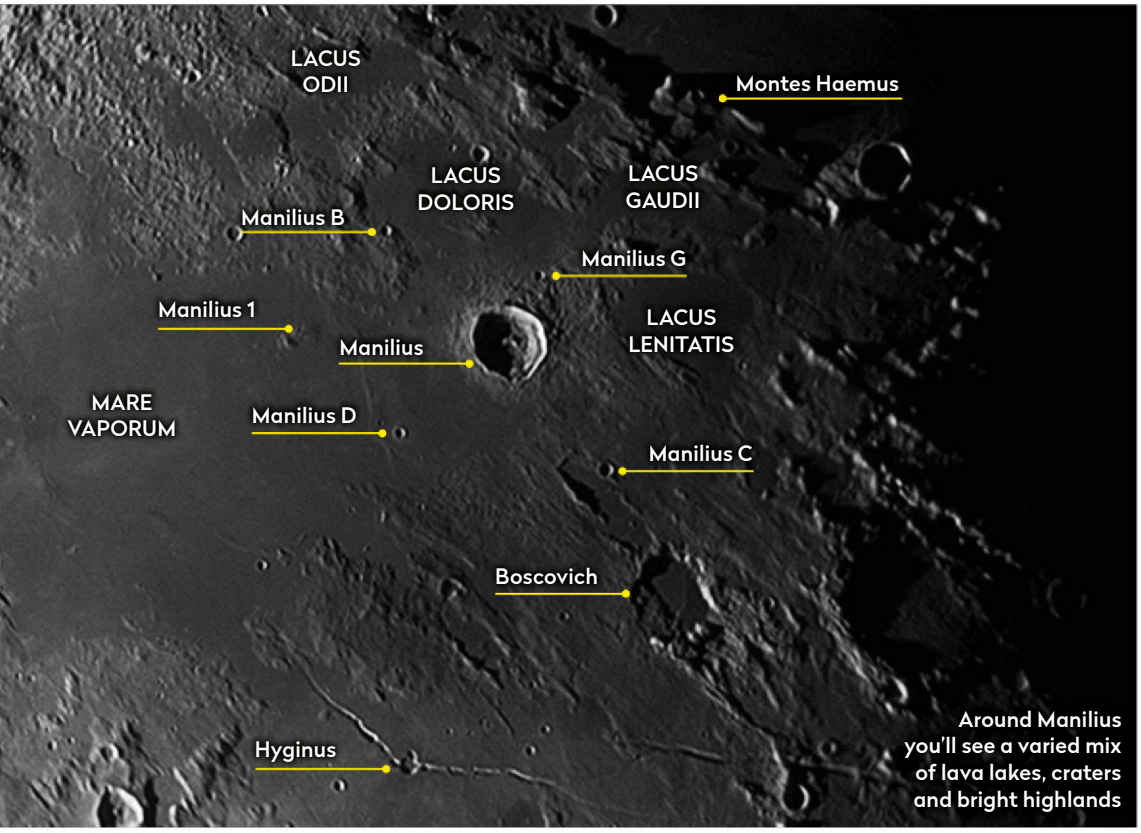
MORE **ONLINE**

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH

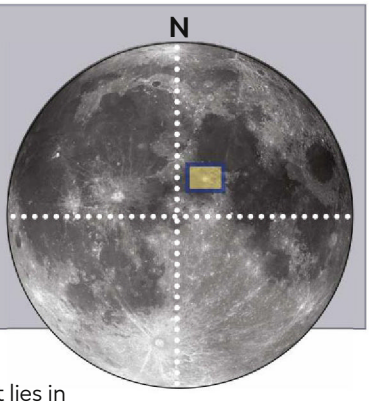
January's top lunar feature to observe



Around Manilius you'll see a varied mix of lava lakes, craters and bright highlands

Manilius

Type: Crater
Size: 40km
Longitude/Latitude: 9.1° E, 14.5° N
Age: Approximately 1.1–3.2 billion years
Best time to see: Five days after full Moon (12/13 January) or six days after new Moon (28 January)
Minimum equipment: 50mm refractor



Manilius is a distinctive 40km crater that lies in the northeast region of **Mare Vaporum**. Its rim appears sharp and well-defined, with a shape that follows a circular profile to the east, but has distinct undulations across a section to the west. The section to the south appears to be pushed further southward than it should. Bright outer ramparts lead up to the upper rim lip. These are extensive and contrast well with the dark lava surface of Mare Vaporum. The ramparts remain close to the crater's rim in the west, extending away from the rim edge by 10km. In the east they are more extensive, extending 36km in a northeast direction and 75km to the southeast.

Inside Manilius, the 2.4km-high crater rim drops altitude steeply, levelling out at an inner shelf defined by a concentric mound of material approximately 4km wide. This then falls further to the inner floor, which is populated by a bright central mountain complex. When the Sun angle is high, as would be the case near to full Moon, Manilius stands out extremely well. Surrounded by dark mare lava, the rim edge appears bright with a darker interior surrounding a bright central mountain peak.

The surrounding region is full of interest. To the west you'll find the dark lava of 230km **Mare Vaporum**. To the north and east lie patches of dark lava delineated by highland regions: **Lacus Doloris** (111km x 80km, 'Lake of Sorrow') to the north, **Lacus Gaudii** (121km x 100km, 'Lake of Joy') and **Lacus Lenitatis** (121km x 73km, 'Lake of Softness') to the east. North of Lacus Doloris is **Lacus Odii** (70km x 70km, 'Lake of Hate'). It's a veritable Lake District of emotions!

Manilius is a ray crater, but it can be tricky to follow its delicate rays across the dark lunar surface due to the intermix of dark lava patches and bright highland regions. There is a distinct lack of large craters nearby. Located 18km northeast of Manilius's rim edge is 5km **Manilius G**, a good example of a bowl-shaped crater. The 6km **Manilius B**, 64km to the northwest, 5km **Manilius D**, 53km to the southwest and 7km **Manilius C**, 62km to the southeast all exhibit a similar bowl-shaped appearance.

While you're looking at Manilius, take a look 26km immediately to the west of its rim where you'll find a tiny, 1.6km, unnamed dark haloed craterlet looking quite distinctive against a brighter ejecta backdrop. To the west of Manilius D is a wrinkle ridge running north–south across the surface of Mare Vaporum. Locate the upper portion of this ridge and look immediately west of it where you'll find a small 600m-high mountain with a 12km-wide, 180m-high dome, **Manilius 1**, immediately to the east. This is best seen when the terminator is nearby and the Sun angle low.

When the Sun angle is high, crater Manilius stands out extremely well

South and slightly east of Manilius is a dark, almost rectangular patch of lava, leading to the battered remains of 46km **Boscovich**, its broken floor criss-crossed by the 1km wide cracks of **Rimae Boscovich**.

PETE LAWRENCE X 3

COMETS AND ASTEROIDS

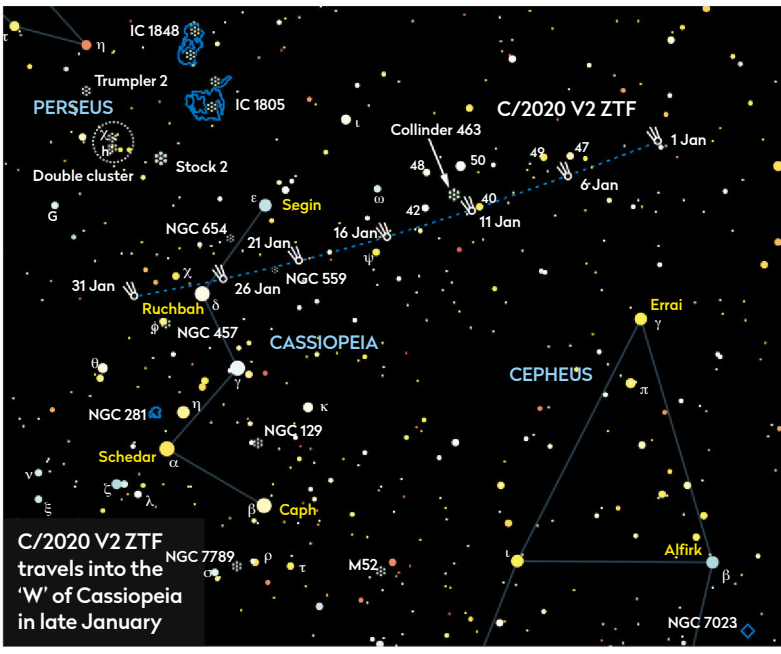
Another bright comet to follow this month, as C/2020 V2 ZTF moves into Cassiopeia

With all eyes tuned to comet C/2022 E3 ZTF and its potential rise to naked-eye visibility, it is worth noting that there is another reasonably bright comet visible during January. Comet C/2020 V2 ZTF starts the month in northern Cepheus, around 7° from Polaris (Alpha (α) Ursae Minoris). From here, it moves south to pass very close to mag. +2.7 Ruchbah (Delta (δ) Cassiopeiae), ending the month 3° south of this star.

It maintains a fairly constant magnitude, starting the month at +9.3 and ending it at +9.2. That is on the edge of binocular visibility, but a small telescope is probably the best way to go.

C/2020 V2 ZTF passes very close to mag. +5.3 40 Cassiopeiae on the evening of 11 January, a track that then takes it 1° to the west of mag. +5.7 open cluster Collinder 463 in Cassiopeia on the following night (12/13 January). It is a fraction over 0.5° from mag. +4.7 Psi (ψ) Cassiopeiae on the evening of 17 January.

Its southward track takes it into the main W-shaped body of Cassiopeia during the last week of January. On the night of 23/24 January it passes just west of the mag. +9.6 open cluster NGC 559. The easiest time to catch the comet will be on the evening of 27/28 January when it passes 15 arcminutes to the west of Ruchbah. There is a 42%-lit waxing crescent Moon in the sky on this date, but this sets around half-past midnight.



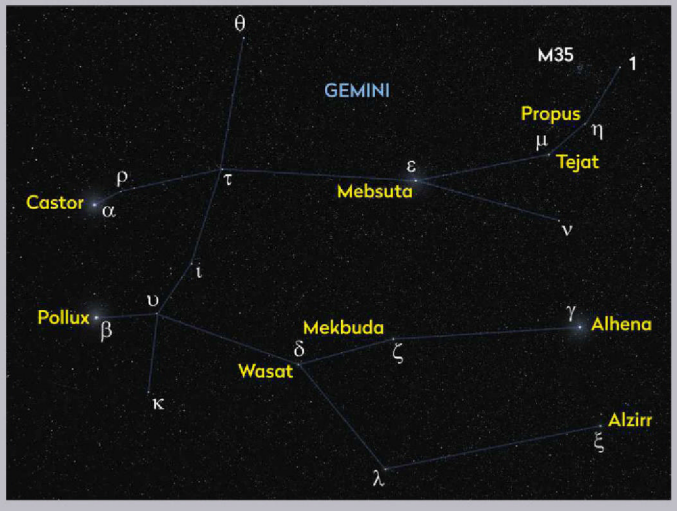
Observing after moonset will give the darkest skies and the best chance of seeing the comet.

C/2020 V2 ZTF was discovered by the Zwicky Transient Facility (ZTF) at the start of November 2020 when it appeared at 19th magnitude. The comet reaches perihelion in May 2023.

STAR OF THE MONTH

Alhena, Gemini's 3rd-brightest star and Pollux's left foot

▼ **Alhena is easy to see with the naked eye**



Alhena (Gamma (γ) Geminorum) is a bright star in Gemini marking the position of the twin Pollux's left foot. Its name is derived from the Arabic word for a brand applied to the neck of a camel.

It is the third-brightest star in Gemini and stands out in a region with few other stars to rival it, roughly midway between the Twin stars Castor (Alpha (α) Geminorum) and Pollux (Beta (β) Geminorum), and Betelgeuse (Alpha (α) Orionis). Compared to mag. +1.6 Castor, at mag. +1.9 Alhena is not far behind in brightness.

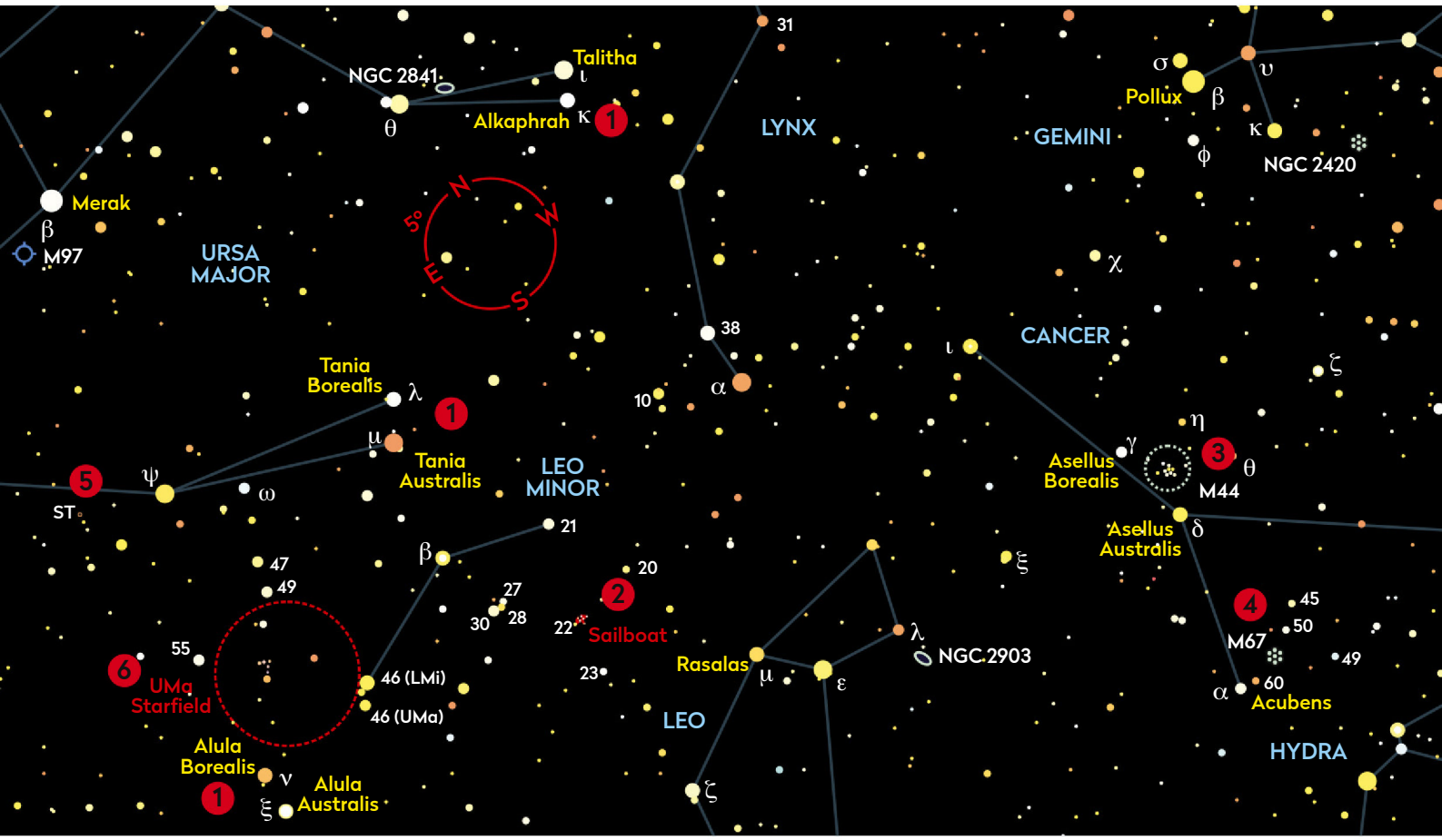
Alhena lies 109 lightyears away. At that distance, to appear as bright as it does to us it must be 123 times more luminous than our Sun. Its spectral classification is A1 IV + G, which means it is a white (A1) subgiant (IV). The '+ G' refers to a G-type companion that, with the primary, forms a spectroscopic binary system with a period of 12.6 years. The primary has a mass 2.8 times larger than our Sun, while the secondary's mass is 1.1 times that of our Sun. The orbit of both stars around their common centre of mass is known to be highly elliptical: with an average separation of 8.5 AU, it brings the pair as close as the Earth–Sun distance and as far apart as Uranus is from the Sun.

Alhena was occulted by the asteroid 381 Myrrha in 1991, an event which revealed that Myrrha has a diameter of 140km and that the spectroscopic binary companion is 200 times dimmer that Alhena.

BINOCULAR TOUR

With Steve Tonkin

In our New Year jaunt, we track hoof-prints, little clouds and an upturned boat



1. The Three Leaps of the Gazelle

10x 50 We begin with an asterism that contains only six stars, in three evenly-spaced pairs, spread over 30° of sky. In North African sky lore these are the hoof-prints left by a gazelle that, startled by a lion (Leo is at the south of the chart), leapt from the watering hole. Binoculars will help to bring out their colour differences, ranging from brilliant-white Kappa (κ) Ursae Majoris to orange Alula Borealis (Nu (ν) Ursae Majoris). ☐ **SEEN IT**

2. The Sailboat

15x 70 Use the chart to identify the location of 22 Leonis Minoris. This giant star is in the centre of a triangle made by 20, 23 and 28/30 Leonis Minoris. Once you have it in your binoculars, you will notice that 22 itself is the brightest of a group of nine stars that form the shape of an inverted sailing dinghy. The brighter four stars form the hull, while the keel and orange mast are picked out by 9th-magnitude stars. ☐ **SEEN IT**

3. Praesepe (The Beehive Cluster, M44)

10x 50 Just above Asellus Australis (Delta (δ) Cancri) you may see with your naked eye a little cloud of stars. The ancient Greeks saw the same, hence their name for it: Nephelion ('little cloud'). Binoculars show it to be brighter in the middle. This is due to mass segregation, a phenomenon in which interactions between heavy and light stars cause the light ones to move faster, so they end up a greater distance from the cluster centre. ☐ **SEEN IT**

4. M67

15x 70 Slightly less than 2° west of Acubens (Alpha (α) Cancri), your binoculars will unveil a misty patch that, like Praesepe, is brighter in the middle due to mass segregation. It contains about a hundred stars that are the same type and age as our Sun, which started life in a cluster like this. These solar proxies, coupled with their relative proximity to us (2,700 lightyears), makes M67 one of the most studied open clusters. ☐ **SEEN IT**

5. ST Ursae Majoris

10x 50 This red giant star 2,400 lightyears away is one of the 1,777 variable stars identified by Henrietta Swan Leavitt but, unlike the Cepheid variables for which she discovered the period-luminosity relationship, ST is a semi-regular variable. It is circumpolar and its magnitude varies between +6.0 and +7.2 over a period of 81 days – ideal if you are learning to observe variable stars with binoculars. ☐ **SEEN IT**

6. 51 Ursae Majoris starfield

10x 50 There is a lovely starfield bounded by Alula Borealis and 55, 49 and 46 Ursae Majoris. Right in the middle there is a 'figure 7' comprising six stars ranging in magnitude from +9.0 to the +5.8 red star at its foot. Surrounding this, in a single field of view, are about another hundred stars of a wide range of colours and brightnesses, including an easy to spot coloured pair 1° below the foot of the '7'. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

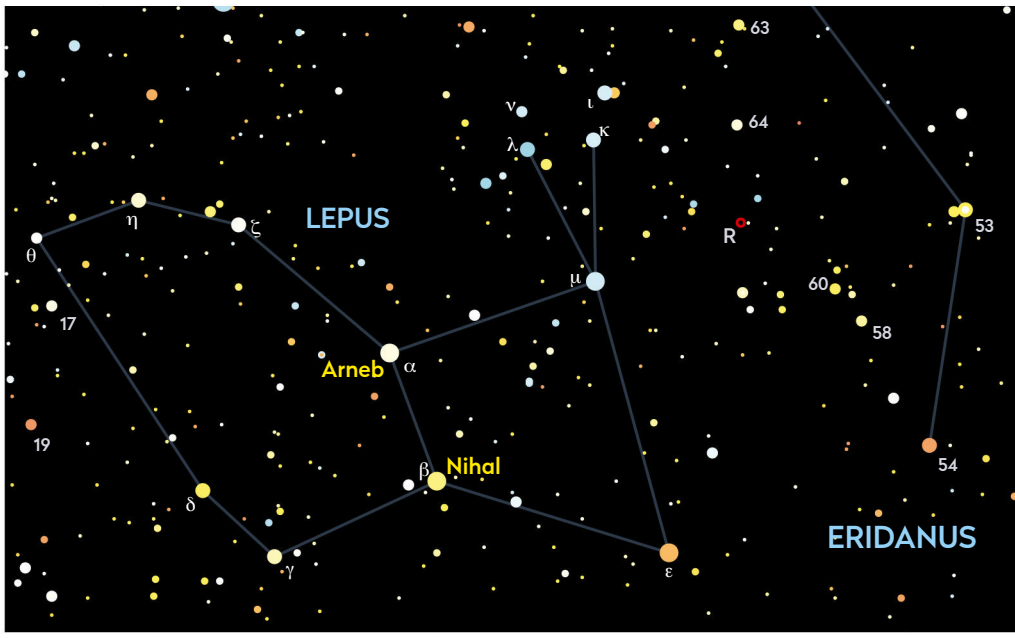
Be on red alert for this month's challenge to hunt for the reddest star you can find

Star colours can be hard to perceive. The difference between a hot blue-white star and a white star may not always be obvious. However, red stars are a different matter. Typically appearing to our eyes as orange, in the star universe red equates to cool. Your challenge this month is quite simple: find and observe or photograph the reddest star you can.

There are plenty of stars whose redness isn't too hard to determine. In the winter sky the two obvious naked-eye candidates are Betelgeuse (Alpha (α) Orionis) and Aldebaran (Alpha (α) Tauri).

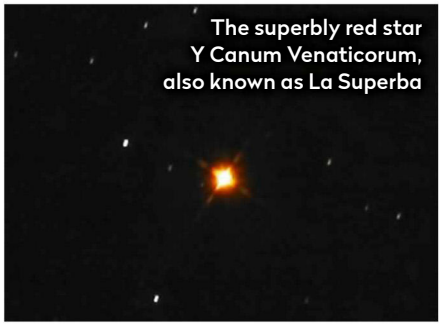
Star redness is quantified by a value called the B-V index. This is calculated by determining the star's apparent magnitude through a standard blue (B) filter and a standard visual filter (V). The more positive the number, the redder the star. The Sun has a B-V index of +0.66, Betelgeuse is +1.85 and Aldebaran +1.54.

There are many sources of B-V information available for no cost. Examples include the excellent freeware planetarium programs Stellarium and Cartes du Ciel. To begin tracking down some candidate stars, you could spend some time looking through their displays, and clicking on objects that appear reddish. Then go out and observe the night sky, highlighting potential targets for study and checking them later in a planetarium program. Alternatively you could search for downloadable lists of red stars. There are plenty out there to choose from, so just start by searching for keywords such as 'red stars catalogues astronomy'.

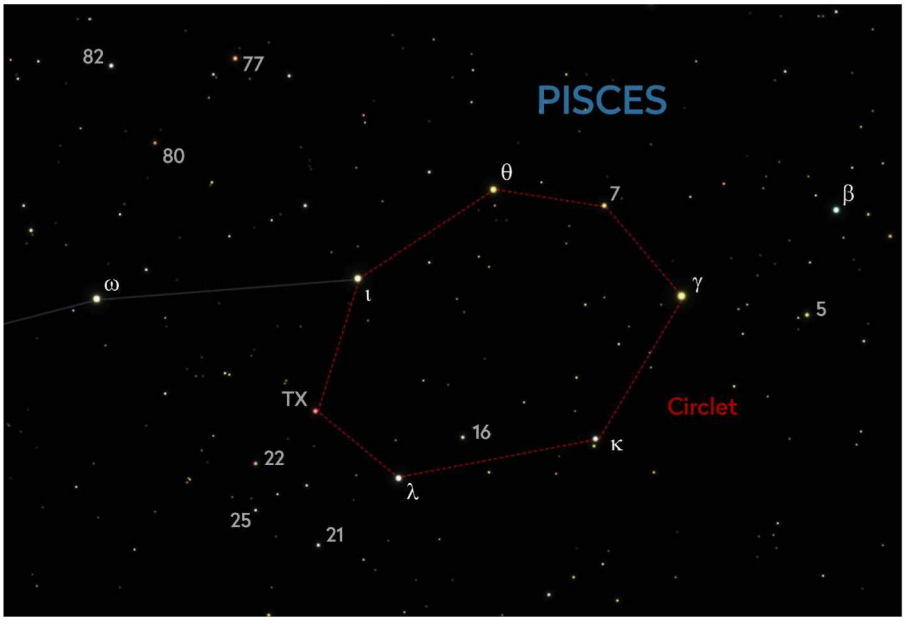


▲ **R Leporis is a very red star in Lepus, close to the border with Eridanus**

Let's give you a few fine examples to get you started. Erakis (Mu (μ) Cephei) has a B-V index of +2.35. With a hint of its colour visible to the naked eye, Erakis has a definite orange hue when seen though binoculars. R Leporis, also known as Hind's Crimson Star, is another classic. This is a variable with a magnitude range of +5.5 to +11.7 and period of 427 days, appearing at its reddest when at the bottom of that range. When close to minimum brightness, R Leporis has a B-V of +5.7. When at its brightest this changes to a B-V of +3.5. Currently the star should be close to minimum brightness, about to start the climb back to maximum. TX Piscium is another great one and easy to find as it is part of the Circlet asterism in the constellation of Pisces.


The superbly red star Y Canum Venaticorum, also known as La Superba

Another fantastic example is mag. +5.4 Y Canum Venaticorum, also known as La Superba. This has a B-V of +3.0 and is relatively easy to find. Simply take the line from Cor Caroli (Alpha (α) Canum Venaticorum) to Chara (Beta (β) Canum Venaticorum) and rotate it by 90° clockwise around Chara. The rotated end will then point at this beautiful red star.



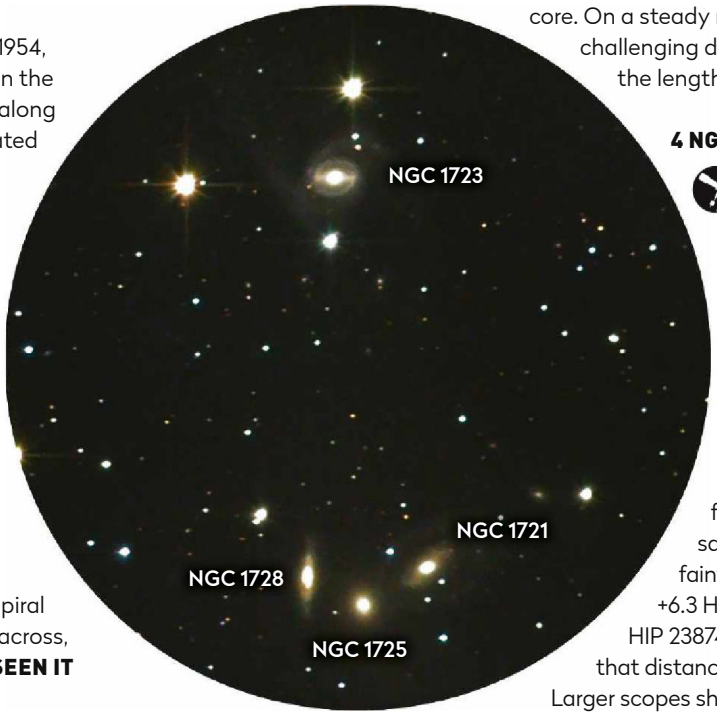
▲ **Bright red TX Piscium is an easy find, marking the east side of the Circlet asterism in Pisces**

DEEP-SKY TOUR

This month we head south of Orion for some lovely targets in northern Lepus, the Hare

1 NGC 1954

We'll start with NGC 1954, the brightest galaxy in the triple galaxy group HDCE 0361, along with NGC 1957 and IC 2132 situated either side of NGC 1954. The group is midway between mag. +3.5 Zeta (ζ) and mag. +4.3 Lambda (λ) Leporis. With an integrated magnitude around +12.8, NGC 1954's core is just visible with a 150mm scope but, never reaching a good altitude from the UK, may be a struggle. Larger instruments show the core brightening to a star-like point. An elongated outer halo can be seen, almost an arcminute long and half an arcminute wide. This is a huge spiral galaxy over 200,000 lightyears across, 144 million lightyears away. ☐ **SEEN IT**



▲ **Your fifth target is impressive barred spiral galaxy NGC 1723, the outlier to a huddle of three fainter galaxies**

2 IC 418

Our next target is the planetary nebula IC 418, located 1.9° northwest of NGC 1954. This is a lovely, bright object with an obvious central star visible through smaller scopes. Using a high power, the only issue with seeing the central star comes from the extended brightness of the 10-arcsecond disc of the nebula. Larger instruments show a definite elongation in the nebula disc. IC 418 is also known as the Spirograph Nebula because high-resolution images show a delicate mesh pattern reminiscent of those made using the toy of the same name. It lies 3,600 lightyears from Earth and appears to shine with an integrated magnitude of +9.3, the central star being mag. +10.3. ☐ **SEEN IT**

3 NGC 1888

We continue northwest to our next target, edge-on spiral NGC 1888. This sits 1.7° northwest of IC 418, or find it by extending the line from mag. +3.3 Mu (μ) through mag. +4.3 Lambda (λ) Leporis about half that distance again. The galaxy is mag. +12.8 and part of the ARP 123 group, along with NGC 1889. The pair are suspected to be merging. Low UK altitude makes NGC 1888 tricky; larger apertures are recommended, which show a thin ellipse with mag. +14.1 NGC 1889 immediately northeast of the core. On a steady night, try to spot the challenging dark dust lane running along the length of NGC 1888. ☐ **SEEN IT**

4 NGC 1784

Our next target is a little brighter. Spiral galaxy NGC 1784 shines at mag. +11.8, an elongated glowing patch 3 x 1 arcminutes in size through a 250mm scope. The best way to locate it is to use the Hare's ears marked by the mag. +4.3 stars Lambda (λ) and Kappa (κ) Leporis. Extend the line from Lambda to Kappa for the same distance again to arrive at fainter mag. +6.0 HIP 23831 and +6.3 HIP 23874. Extend the line from HIP 23874 through HIP 23831 six times that distance again to arrive at NGC 1784. Larger scopes show a distinct oval halo with a 'broken' core within. A 300mm scope shows the centre of the core to be star-like. ☐ **SEEN IT**

5 NGC 1723

We hop from Lepus into Eridanus for mag. +12.5 barred spiral galaxy NGC 1723, just outside the northwest corner of Lepus. Relocate the stars HIP 23831 and HIP 23874 from target 4. Extend their line, passing mag. +7.2 HIP 23627, then mag. +6.8 HIP 23405, before arriving at mag. +5.4 63 Eridani. NGC 1723 sits 0.7° south of 63 Eridani and 0.6° west of HIP 23405. The galaxy is face-on, which reduces its brightness. It appears as a central core and a faint halo within a triangle of mag. +9.8, +10.0 and +11.2 stars. If you can find it, look approximately 7 arcminutes south where you may also see a fainter trio of galaxies: NGC 1721, 1725 and 1728. ☐ **SEEN IT**

6 Abell 7

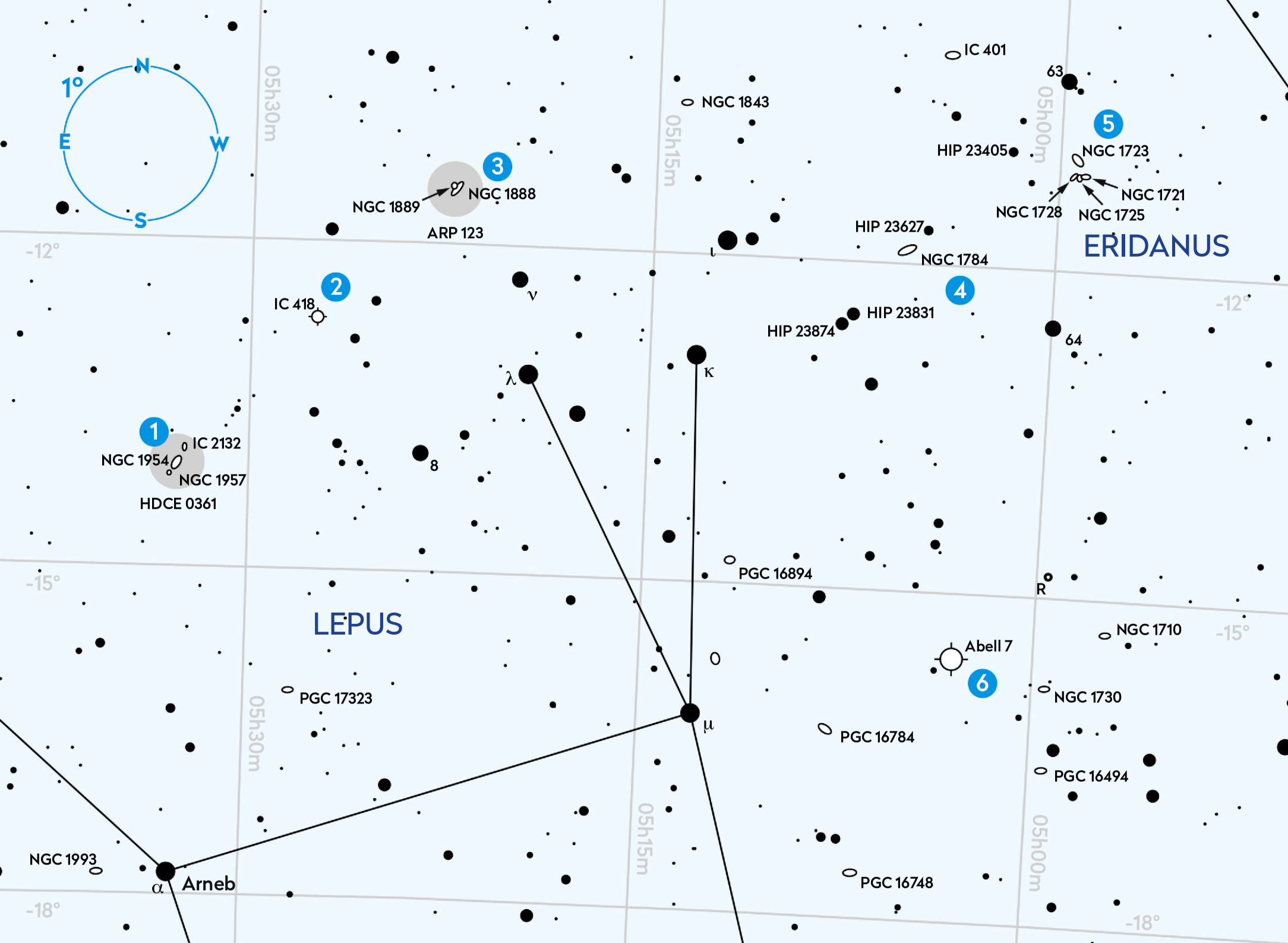
Finally, a challenging planetary nebula in Lepus. To locate the region of sky in which it sits, draw a line from mag. +2.6 Arneb (Alpha (α) Leporis) through mag. +3.3 Mu (μ) Leporis, extending it a little under half that distance again, tracking fractionally south as you go. Alternatively, look 1.1° south of mag. +6.7 HIP 23560. It is a faint object with an integrated magnitude around +13.0, but to compound this it is also large, appearing around 10 arcminutes across. This gives it a low surface brightness. It suits a light-bucket type instrument, such as a short-focal-length large Dobsonian; a 330mm scope at x100 magnification shows it as a faint glow. A UHC filter should prove helpful here. The central star has a magnitude of +15.4. ☐ **SEEN IT**

WALTER PRIMIK/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions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NGC 1954
NGC 1957
HDCE 0361
IC 418
NGC 1889
NGC 1888
ARP 123
NGC 1843
IC 401
63
HIP 23405
NGC 1723
NGC 1721
NGC 1728
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NGC 1784
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PGC 16784
PGC 16494
NGC 1993
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Arneb
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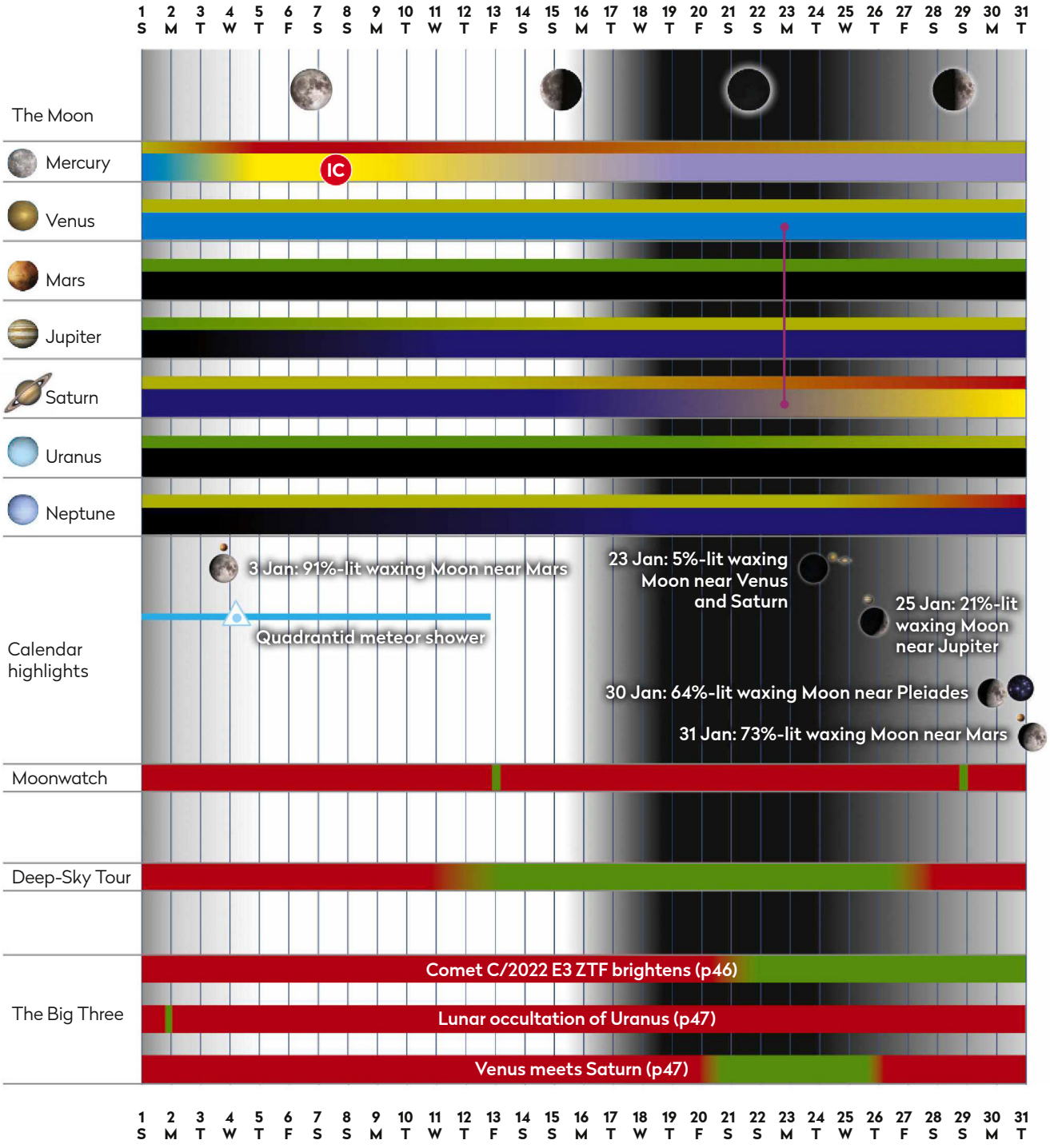
AT A GLANCE

How the Sky Guide events will appear in January



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

- IC — Inferior conjunction (Mercury & Venus only)
- SC — Superior conjunction
- OP — Planet at opposition
- Meteor radiant peak
- Planets in conjunction

- Full Moon
- First quarter
- Last quarter
- New Moon

CHART BY PETE LAWRENCE

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Spaceflight takes off in the UK

As the first-ever UK space launch draws near, **Shaoni Bhattacharya** takes a deeper look at Britain's spaceflight industry

This is the year that the UK hopes to demonstrate it is a serious player in space. It already has established expertise in space science and satellite production, but 2023 will see it become a launch-capable nation. According to the UK Space Agency, our nation offers the right mix of regulations, environment, business and geography for commercial launch services, with the aim of attracting business in an industry worth $20 billion globally. With the UK due to host its first rocket launch (and the first from European soil) in late 2022 from Spaceport Cornwall, and two more sites hoping to begin operations in 2023, these hopes may not be unfounded. Meanwhile, the UK is also building its relationships with private companies and spacefaring nations, and is already involved with several major projects that could see UK-built tech touching down on the surface of the Moon. It's an exciting time to take a deeper dive into the world of UK spaceflight. ▸

MARK GARLICK

LauncherOne leads the way in the race to establish the UK as a world-class launch site

ILLUSTRATION

ILLUSTRATION

The repurposed Boeing 747 Virgin Orbit will send satellites into space

From Cornwall to orbital

The first UK space launch will depart not from a launch pad, but a runway

Based at Newquay Airport, Spaceport Cornwall is able to host horizontal launches, which involve a carrier aircraft taking off from a runway to reach the desired launch altitude and releasing a rocket in mid-air. Virgin Orbit's modified Boeing 747, called Cosmic Girl, will release the LauncherOne rocket at an altitude of around 35,000 feet (10,700 metres). The system can transport up to 300kg of cargo into orbit.

The 'Start Me Up' mission from Spaceport Cornwall is due to launch by the end of 2022, and was granted a licence to fly by the Civil Aviation Authority on 16 November, though a launch date was yet to be announced at time of writing. It will deploy seven payloads into low-Earth orbit. These will be a range of satellites, with five from the UK, including the IOD-3 Amber satellite developed by the Satellite Applications Catapult and Horizon Technologies, and built by AAC Clyde Space. It is the first of more than 20 satellites that will be in the Amber constellation, designed to provide governments and customers with maritime data to help combat problems like illegal fishing, smuggling and trafficking.

Notably, among the UK payloads is the test launch of the world's first returnable and reusable space-manufacturing platform, called ForgeStar-0. Made by Welsh company Space Forge, this platform eventually aims to harness space to make materials off-Earth in microgravity conditions.

Also on board, in another first, is the Sultanate of Oman's first-ever satellite, AMAN, for Earth observation. A further Polish satellite is also to be deployed as part of SatRev's STORK constellation for Earth observation.

▲ Once at altitude, the plane will release its satellite-bearing rocket

▲ Melissa Thorpe, head of Spaceport Cornwall, with the LauncherOne

The Scottish Space Race

A pair of spaceports are vying to stage the first vertical launch from UK soil

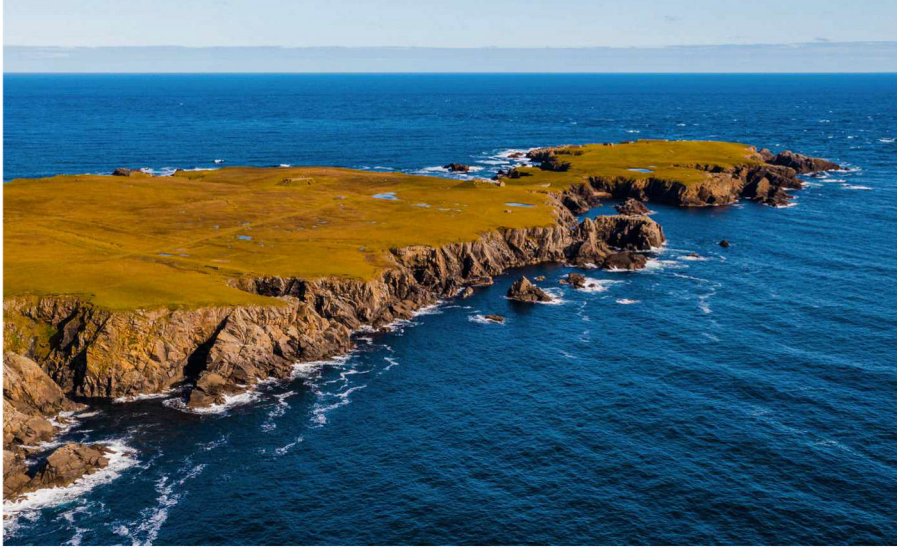
With the first horizontal launch on its way, the race is now on between SaxaVord on Unst in the Shetland Islands, the most northerly point of the UK, and Sutherland on the northwest Scottish coast to stage the UK's first vertical rocket launch. These two facilities will launch satellites using traditional rockets taking off directly from a launchpad on the ground.

SaxaVord aims to be a multi-use spaceport supporting launches by several operators, but Lockheed Martin is keen to be the first to launch there as part of the UK Space Agency's Pathfinder launch. It is bringing over a new rocket from the US called RS1, by ABL Space Systems, that can carry payloads up to 1,350kg. The launch will carry up to six CubeSats into low-Earth orbit, deployed by a free-flying Orbital Manoeuvring Vehicle built by Moog, currently in production in Reading.

"They've started to pour the concrete [in SaxaVord] and put in the bits of infrastructure needed to support this," says Nik Smith, regional director for Lockheed Martin UK. "From a space perspective, they've got a great location. It's fantastic for polar orbits where a lot of low-Earth orbit communications satellites will be operating."

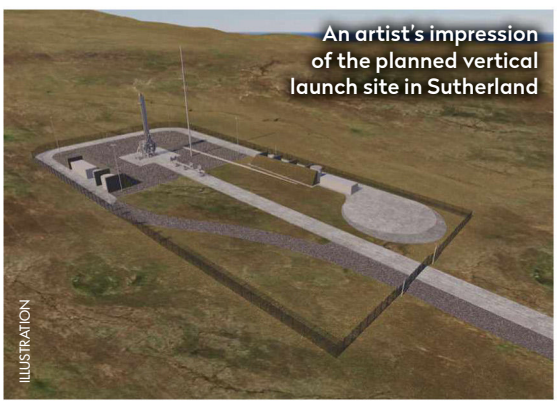
Sutherland Spaceport, on the A' Mhòine peninsula on the northern coast of the Highlands, offers similar benefits for reaching these orbits. Both Scottish locations also offer remote flight paths that do not traverse populated areas, but rather vast expanses of sea. British rocket company Orbex is planning to launch its rocket vertically from Sutherland, and last November signed a 50-year sub-lease on the spaceport with the development agency Highlands and Islands Enterprise. It plans to launch up to 12 vertical rockets a year from Sutherland to carry satellites to low-Earth orbit.

While the UK Space Agency has invested most in these three spaceports, four other sites have also been under consideration. These include three more in Scotland: North Uist in the Outer Hebrides, Spaceport Machrihanish in Argyll, Prestwick Spaceport in South Ayrshire; and Spaceport Snowdonia in Wales. ▸



▲ Skaw in Unst, the northernmost settlement in the UK and the most direct route to orbit from Europe

► One of three launch pads being built by SaxaVord in Skaw to send small rockets into low-Earth orbit



An artist's impression of the planned vertical launch site in Sutherland

ILLUSTRATION

▼ Orbex's Prime rocket: the Scottish company is to build and run Sutherland spaceport

Q&A with Ian Annett of the UK Space Agency

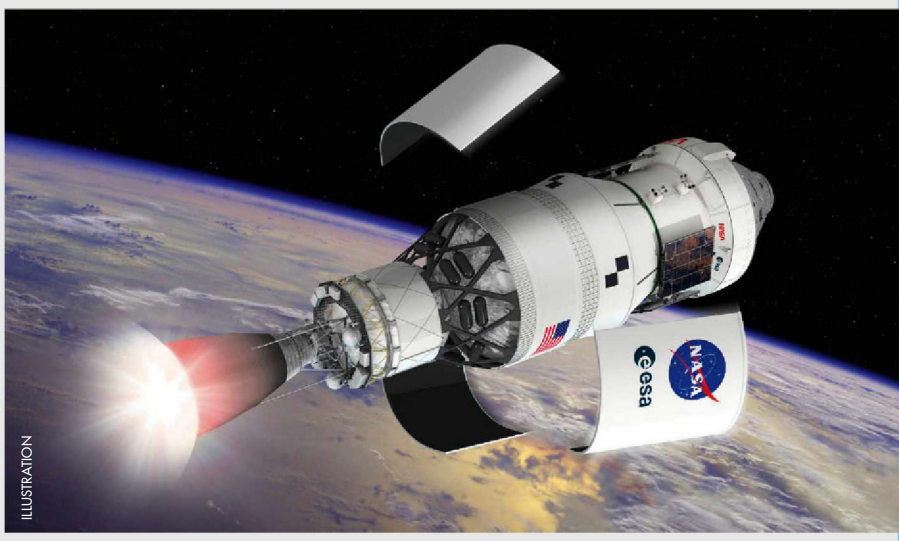
The UK Space Agency has been instrumental in guiding the developing British space sector

It feels like there's a lot going on in spaceflight in the UK. Are we on the cusp of something?
There is an immense amount going on. I think we're in the most exciting decade for space since the 1960s. It's gripped the world, not only for its inspiration but because it's got real economic benefits globally and certainly nationally for the UK.

We want to establish a commercial vertical and horizontal satellite launch capability from the UK. Really what we're aiming at is the economy in low-Earth orbit (LEO) – that's burgeoning. Back in 2012, something like 50 satellites launched into LEO, and by 2019 I think it was 900; but last year, there were 1,900 launches into space, 1,700 of which were satellites into LEO. So it's a rapidly growing economic opportunity for the UK, whether that be for telecommunications, Earth observation or indeed in more normal technologies like manufacturing interfaces, we can grow crystalline structures in a much better and more efficient manner [in space]. You're only really limited by your imagination.

Why the UK? Are there advantages geographically, politically or legally that make the UK a good place for spaceflight?
I think all of the above. The UK is a good place to do business. It's got a stable legal framework. Under the Space Industry Act in 2020 we have introduced the most forward-leading and flexible set of space regulations. If you look at the insurance market for satellites and launches, you'll find the vast majority of them come to London.

But more fundamentally, our space industry has an immense amount of skill, from designing satellites to building them. More small satellites are built in Glasgow than anywhere else in Europe. Global businesses like Inmarsat and OneWeb have their operation centres here. The UK is a great place to come to for developing applications that can exploit that data [from space], whether it be Earth observation or navigational data. The one thing that was really missing in that full spectrum of capability is launch. And if you can deliver that from a single nation, it makes it really, really attractive. That's why we've put £40 million into the launch programme.



ILLUSTRATION

▲ Tech on board Artemis's Orion module has had UK involvement via the European Space Agency

What about human spaceflight and the UK's role in the Artemis programme?
The UK is very forward-leaning in terms of being involved in the global human spaceflight projects, but we very much do that through our partnership with the European Space Agency (ESA). Through its association with ESA the UK will make critical contributions towards Artemis: whether it's through parts of the Lunar Gateway that's being built, or the European Service Module as part of the Orion capsule – there's a lot of UK technology within that, and also some UK academic thinking through the likes of Imperial College.

What are you looking forward to in 2023 in terms of spaceflight in the UK?
One of the key things that keeps me driving forward with launch, and I hope I can reflect on in 2023, will be how many thousands of youngsters we have inspired to look up at the stars, get involved in the space sector, and be part of something that can improve our lives here in the UK, and also help to develop us economically.

Ian Annett is the Deputy CEO for Programme Delivery, responsible for national space programmes across the UK Space Agency

ESA/D. DUCROS, UNIVERSITY OF LEICESTER, SPACEBIT, CHRIS ALAN WILTON/ALAMY STOCK PHOTO, AIRBUS, GETTY

Space hubs, companies and bridges

The UK is growing as a centre for spaceflight innovation

▲ **Space Park Leicester, where university research and business expertise meet**

As well as spaceports, other initiatives are helping to bolster the UK spaceflight sector, one example of which is Space Park Leicester, which officially opened in March 2022.

"It's a university-owned space facility, built around the idea that we host space businesses in the same facility as the researchers work," says Martin Barstow, their director of strategic partnerships and a professor of astrophysics and space science at the University of Leicester. "Space is expensive. In terms of building things like clean rooms, they're costly. They're beyond the means of small companies."

Making such facilities available in the Space Park reduces the cost of access for small and medium-sized enterprises and start-ups, he adds. They are also able to lean on the academic expertise in space that already exists at the university, which has some 300 people working in the area.

As well as small companies, start-ups and university spin-offs, some aerospace giants such as Lockheed Martin and Northrop Grumman have also joined, setting up small groups that work alongside their larger UK facilities.

"Space is an obvious next step for us for the ambitions that the UK has put in place," says Lockheed Martin's Nik Smith, noting that the UK government has put in "very strong structures around a broad space strategy". These include the UK's Space Strategy and Spaceflight Programme which, combined with capital coming into the country for space, is creating a strong environment for innovation.

The UK's work on building strong international relationships also makes it an attractive hub to reach into new markets. The UK has already signed several partnerships – such as the UK–Australia Space Bridge and a Memorandum of Cooperation with the Japanese Aerospace Exploration Agency – with the aim of increasing international cooperation into the future, and cementing our position as a space power on the international stage.

Shaoni Bhattacharya is a science writer and editor, as well as a short fiction author

Best of British

We highlight three of the dozens of space projects currently underway in the UK

▲ Spacebit

A UK–Ukrainian company that hopes to send the first walking rover to the Moon, on board the Peregrine lander (see **page 32** for more details).

Goonhilly Earth Station ▶

The radio communication site has been operating from Cornwall since 1962, but is getting renewed interest for communicating with lunar missions.

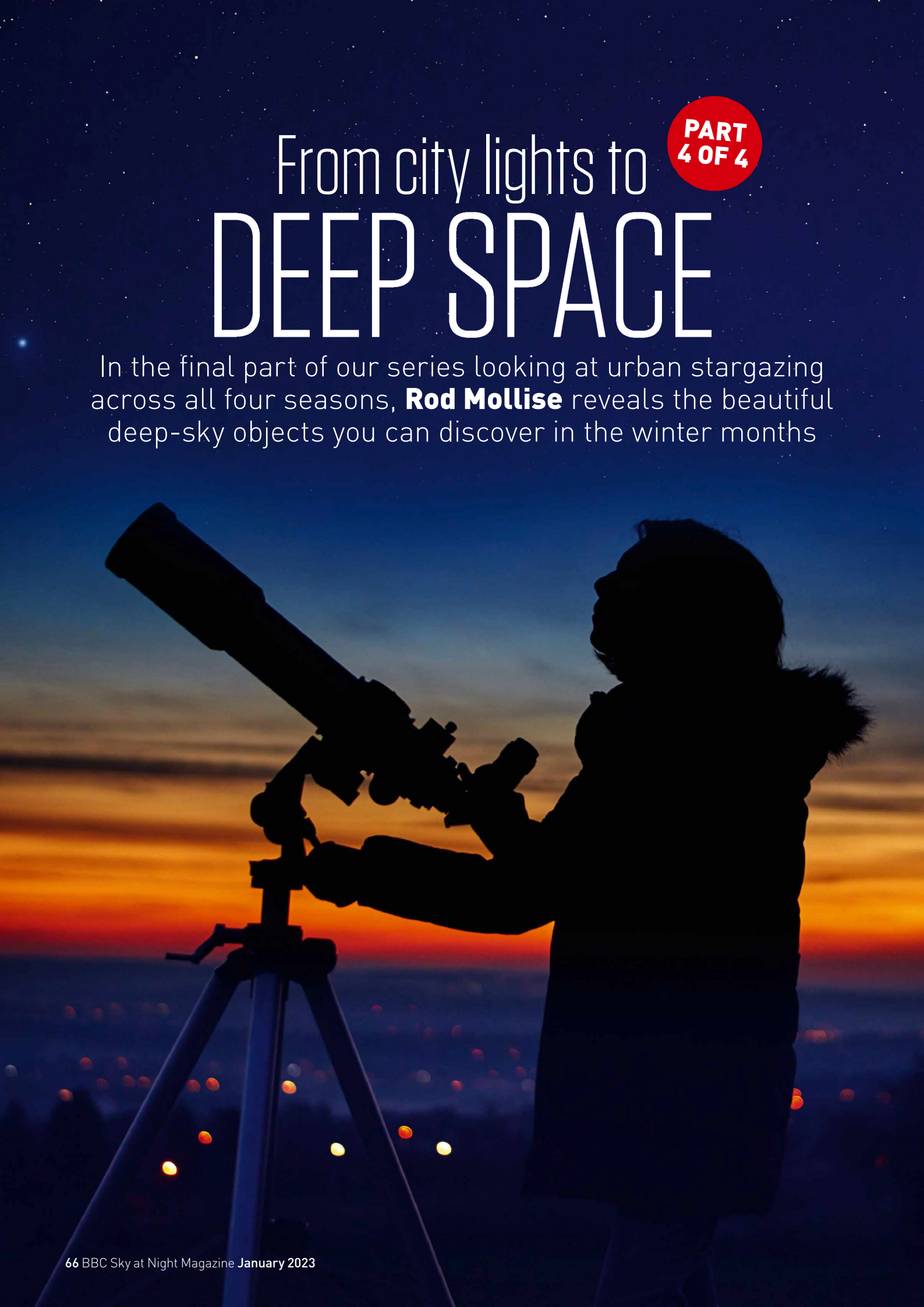
▲ Ariel

Led by University College London and mainly being built by Airbus in Stevenage, Ariel is an ESA mission to characterise 1,000 exoplanets, due to launch in 2029.

PART 4 OF 4

From city lights to DEEP SPACE

In the final part of our series looking at urban stargazing across all four seasons, **Rod Mollise** reveals the beautiful deep-sky objects you can discover in the winter months



Winter is here and with it comes the welcome longer nights. As an urban astronomer, you can spend longer searching out the many deep-sky objects, those galaxies, nebulae and star clusters that are visible, even in brightly-lit areas. The key to seeing them is perseverance – and the right kit.

The most important aspect of any telescope used for deep-sky observing is aperture – the size of its light-collecting lens or mirror – and this applies more so to urban areas. If you contend with light pollution, an aperture of at least 200mm is recommended.

'Uncle' Rod Mollise is an American amateur astronomer and writer who lives near Mobile, Alabama. He is the author of *Choosing and Using a New CAT*

Having a Go-To mount is useful in urban areas too, so you can simply enter the name of a deep-sky object into the hand control for the telescope to move to it. Light pollution reduction (LPR) filters can also help, but they only work on diffuse and planetary nebulae – and are mostly useless for galaxies and star clusters. Tricks to maximise your chances include shielding the telescope from nearby light, jiggling it slightly to catch invisible objects, and using averted vision – looking slightly off to the side of a faint object can make it appear brighter and more detailed.

With these techniques, the right equipment and some perseverance, you'll be amazed at the marvels you can discover in the winter night sky.

Winter sights

So much to see and longer nights to spend discovering these stunning constellations...

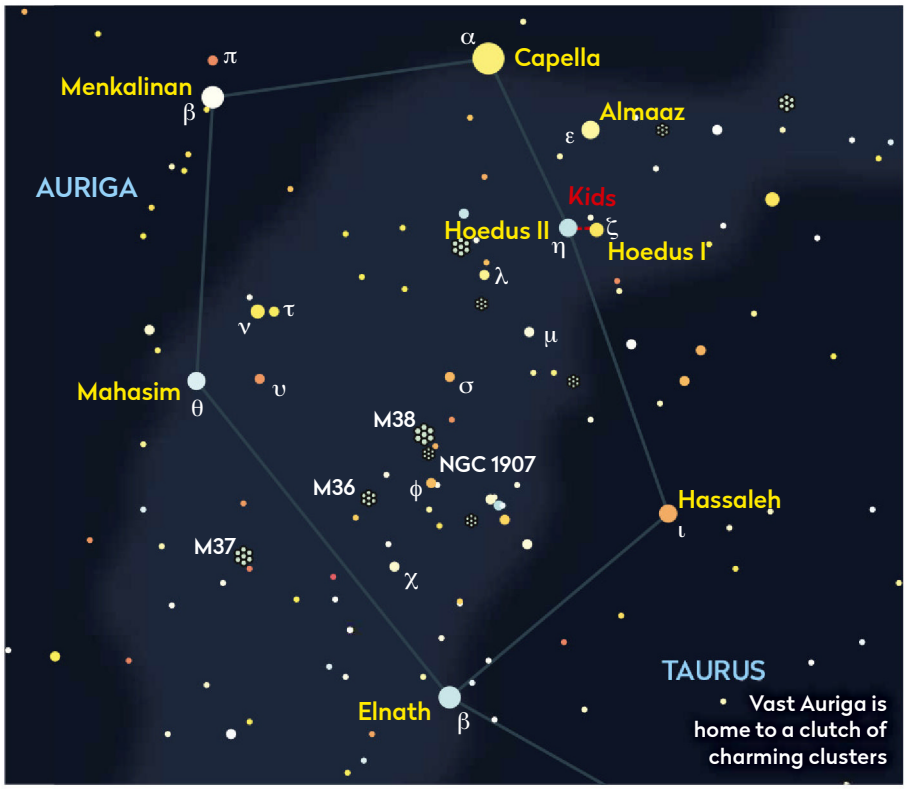
Auriga, the Charioteer

This enormous constellation is on the rise in the east

The sprawling pentagon stick-figure of Auriga is home to both open star clusters and diffuse nebulae. All its nebulae are faint and mostly invisible to urban astronomers, but it is blessed with three beautiful Messier clusters.

The great open cluster **M37** (mag. +5.6, 15' across) is one of the few deep-sky objects that looks wonderful in any telescope under almost any conditions. It's not too large for medium aperture, medium-focal-length telescopes (the larger the focal length of a telescope, the smaller its field of view), but also not so small as to fade into the background in smaller, shorter-focal-length instruments. M37 lies just outside Auriga's stick figure to the east of a line drawn between bright **Mahasim** (Theta (θ) Aurigae) and **Elnath** (Beta (β) Tauri; this 'fifth' star in Auriga's pentagon actually belongs to Taurus).

▲ **Spectacular, rich open cluster M37 is a delight through instruments of any size**



M36 (mag. +6, 10' across) is also an impressive open cluster, 3°41' northwest of M37. Bright and compact, it packs a lot of bright stars into a small area. In a 10-inch reflector, it is slightly oval in shape and festooned with bright suns.

A further 2°18' northwest is the third of the Auriga Trio of open clusters, **M38** (mag. +6.4, 15' across). M38 is rich with brilliant stars, arranged in lines and streamers extending from the centre, hence its name, the Starfish Cluster. In a low-power eyepiece, M38 looks like a cosmic starfish in a dark sea of night.

NGC 1907 (mag. +8.2, 5' across) is a dim open cluster, located 32' southwest of M38. With 8 inches of aperture, you'll see it even in fairly heavy light pollution – although it will look like a nebulous spot rather than a star cluster. ▸

M GUCCI/ISTOCK/GETTY IMAGES, CHART BY PETE LAWRENCE, MICHAEL BREITE/STEFAN HEUTZ/WOLFGANG RIES/CCDGUIDE.COM

You're spoilt for choice for gorgeous deep-sky targets in Orion

some nebulosity should become visible. On the best evenings, streaks of dark nebulosity may become visible crossing M43, especially on its eastern side.

There is one other reasonably bright cloud in Orion, **M78** (mag. +8, 8′ x 6′), a reflection nebula in the northeast of the constellation about 2° northeast of bright **Alnitak** (Zeta (ζ) Orionis), the easternmost star in Orion's Belt. On good evenings, M78 begins to look rectangular rather than oval, and the nebulosity extends further out from the stars.

Orion is also a place of open clusters. So many groupings crowd each other in the area that it is sometimes difficult to tell where one ends and another begins. This is the case for **NGC 2175** (mag. +6.8, 40′ x 30′) in the northeastern part of the constellation, not far from the end of the Hunter's uplifted club. NGC 2175 is on the bland side, but the **Monkey Head Nebula** that envelops the cluster and extends south is not.

Finally, M42's **Trapezium Cluster**, Theta[1] (θ[1]) Orionis, is a remarkable quadruple star – four suns forming a skewed rectangle, a trapezoid. The group is located within M42's nebulosity, 13′ southeast of Nu Orionis.

Orion, the Hunter

Big, bright and easy to spot, this is a must-see constellation

Not only does Orion, the Hunter look like what it's supposed to depict – a huge human figure with a belt and sword – but its stars, which include bright **Betelgeuse** and **Rigel**, also show up well even in heavy light pollution.

The premier deep-sky object of the Northern Hemisphere is **M42** (mag. +4, 1° x 1°30′), the Orion Nebula. This naked-eye object in Orion's sword is obvious even in the worst city skies. While city observers won't see anything close to the nebula's extent as it is visible from dark skies, they should keep the field of the telescope wide enough to take in as much as possible of the spectacle. A relatively mild filter like a UHC-type can help, and an OIII filter will reveal some details that are invisible without it.

M43 (mag. +9, 20′ x 15′) is a detached portion of M42 that is bright enough to have received its own M-number. M43 is easy to find, located on the northern side of the Orion Nebula. In the city, the most noticeable thing in the area is the bright star that M43 surrounds, mag. +6.7 **Nu (ν) Orionis**. Increase magnification to 100–150x, however, and

The Orion Nebula, M42 with the Trapezium Cluster at its heart

On the clearest evenings, M78's misty nebulosity is a sight to behold

CHARTS BY PETE LAWRENCE. CEDIC TEAM/CHRISTOPH KALTSEIS/CCDGUIDE.COM, JOHANNES SCHEDLER/CCDGUIDE.COM, HORST ZIEGLER /CCDGUIDE.COM, GÜNTER KERSCHHUBER/CCDGUIDE.COM

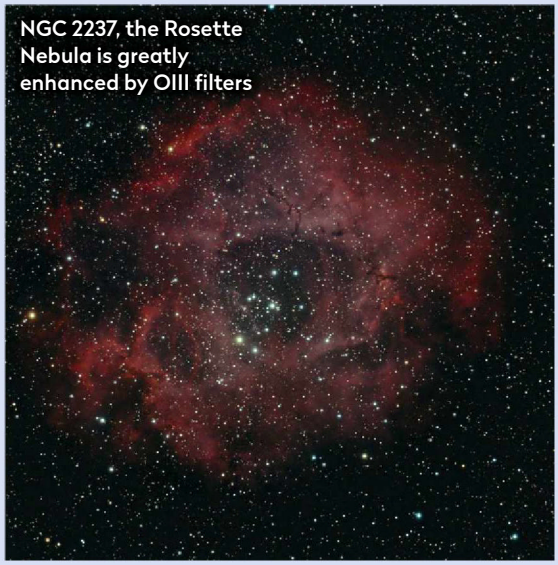
Monoceros, the Unicorn

It's not much to look at, but this constellation still holds treasures

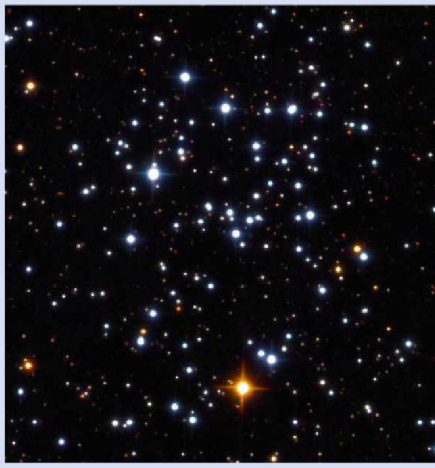
Monoceros lies just east of Orion. In heavy light pollution, its stars may be difficult to see – the brightest sun is a puny mag. +3.9. But there are deep-sky riches waiting to be teased out.

The beautiful Rosette Nebula, **NGC 2237** (mag. +5.5, 1°20' x 1°) is a great, glowing ring of emission nebulosity with a dark centre that looks like a huge Christmas wreath – but it can be challenging to see. You'll find that an OIII-type light pollution filter is the key to seeing the Rosette.

At the centre of the Rosette is the beautiful open star cluster **NGC 2244** (mag. +4.8, 24' across). Unlike the nebula, the cluster is not difficult to see – a bright scattering of stars that form a roughly dipper-shaped asterism.



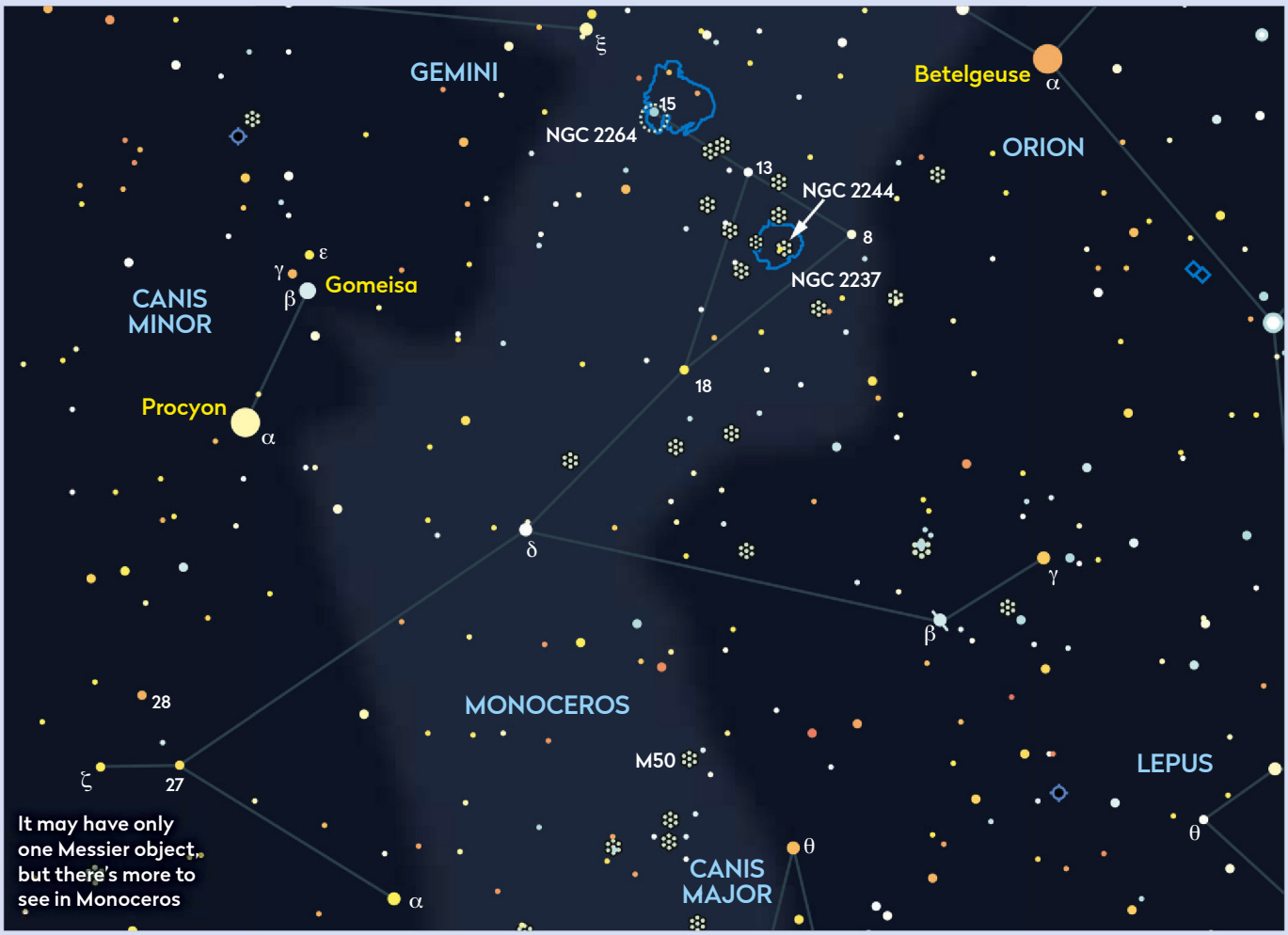
NGC 2237, the Rosette Nebula is greatly enhanced by OIII filters



▲ M50's heart-shaped open cluster of blue-white stars emerges with medium powers

Monoceros has a Christmas tree to go with the wreath. **NGC 2264** (mag. +3.9, 10' x 7'), the Christmas Tree Cluster, is a group of 30–40 bright stars that form (with a little imagination) a recognisable tree shape. The area of the Christmas Tree Cluster is also an area of nebulosity.

M50 (mag. +5.9, 15' across), known as the Heart-Shaped Cluster, lies not far from the border with neighbouring Canis Major. A red star near the cluster's centre provides a nice contrast with M50's many blue-white suns. The grouping is known as the Heart-Shaped Cluster because its arcs of stars form an identifiable Valentine's heart. ▸



It may have only one Messier object, but there's more to see in Monoceros

Gemini, the Twins

This bright constellation dominates the eastern horizon in winter

What makes Gemini stand out is the presence of two bright and beautiful stars only 4.5° apart, mag. +1.9 **Castor** and mag. +1.1 **Pollux**. These stars form the heads of the legendary twins, and a stream of bright stars extends south from each. The best way to visualise Gemini is as a huge 'U' lying on its side.

M35 (mag. +5.2, 25' across), located at the southern end of the constellation at the 'foot' of Castor, the western twin, is one of the finest star clusters in the sky. Easy to find even with a small telescope in heavy light pollution, M35 is a round, dense crowd of bright sparklers almost as large as the full Moon – its brightest stars are mag. +8.0.

NGC 2158 (mag. +8.6, 5' across) is an open star cluster located only 27' southwest of the centre of M35. Despite its closeness to the big cluster, the two are not actually associated. NGC 2158 is 13,000 lightyears out in space, compared to a distance of 'only' 2,800 lightyears for M35. Their placement alongside each other is just a line-of-sight effect. NGC 2158 is a cluster that cries out for aperture.

Planetary nebula **NGC 2392** (mag. +3.5, 48" across) is located a little less than halfway down the constellation, 2°21' east-southeast of the bright star **Delta (δ) Geminorum** (Wasat). Its small size means it can be mistaken for a star. On a good night, 250x magnification will resolve the mag. +10.5 central star, while going up to 300x reveals hints of an inner ring, what's been described as looking like the 'furry hood' of a parka coat, a detail that is more visible in photographs.

Spiral galaxy **NGC 2339** (mag. +12.3, 2.4' across) is on the eastern side of the constellation, 4°13' southwest of mag. +3.5 Wasat. Observing this galaxy requires patience, a good night in the suburbs and at least 10 inches of aperture.

▲ Gemini has lovely clusters, a spiral galaxy and a planetary nebula to discover

Sparkling open cluster M35, with the smaller and more compact NGC 2158 nearby

▲ Larger scopes will reveal the 'furry hood' of planetary nebula NGC 2392

CHARTS BY PETE LAWRENCE. CHRISTOPH KALTSEIS/CCDGUIDE.COM, MICHAEL DEGER/CCDGUIDE.COM, CEDIC TEAM / CHRISTOPH KALTSEIS/CCDGUIDE.COM, JOHANNES SCHEDLER/CCDGUIDE.COM

▲ Wait for marvellous M41, the Little Beehive Cluster near Sirius, to get as high as possible above the horizon

► An OIII or UHC filter will help to reveal amazing NGC 2359, a diffuse bubble of gas thrown off by a star

Canis Major, the Big Dog

Despite skimming the horizon, this constellation has plenty of sights worth seeking out

Although it never gets high enough in the sky to rival other open clusters, **M41** (mag. +4.5, 39' x 39'), the Little Beehive Cluster, is still a marvel – a large group of 60 stars spread across an area larger than the full Moon. Most of M41's suns are bright, making it a naked-eye object from sufficiently dark sites. Luckily, M41 is located in the more northerly area of the constellation, 4° south of **Sirius**, and is somewhat away from the haze of the horizon. To improve the appearance of this group in the city, try using a mild light-pollution filter, a 'Skyglow' or 'Deep Sky'-type filter. This has the effect of darkening the background a bit, but not dimming the bright cluster stars too much. One of M41's more striking features is the strongly orange-red sun near the cluster's centre.

The outstanding nebula, **NGC 2359** (mag. +11.5, 10' x 10'), Thor's Helmet, is a faint cloud of ionised gas. Thrown off by a Wolf–Rayet star, this cloud of gas is just visible from urban sites using a 12-inch Dobsonian reflector and a UHC filter.

NGC 2362 (mag. +4.1, 8' x 8') requires a trip to the far south, to a declination of –24°57'. At best, this cluster only climbs 13° or less into the UK skies, so wait until it is on the local meridian, when it is as high as it gets, before attempting to observe it. Like most open clusters, NGC 2362 is not difficult to catch, and its 20 to 30 stars are obvious in the eyepiece even when it is at low altitude in the sky. In the midst of NGC 2362 is bright-yellow mag. +4.3 **Tau (τ) Canis Majoris**, the Jumping Spider Star. Due to contrast effects, when you jiggle the telescope, the halo of tiny amber suns surrounding Tau appear to move in one direction, while Tau seems to move in the opposite direction – the spider jumps!

The fundamentals of astronomy for beginners

EXPLAINER

Isaac Newton

Anita Chandran takes a look at the life of one of history's most famous astronomers

This month marks the 380th anniversary of the birth of Sir Isaac Newton, one of the most celebrated figures in scientific history, whose wide-ranging contributions touched almost every aspect of modern science.

Born in 1643 near Woolsthorpe, Lincolnshire, Newton was a lonely but determined child. Even as a boy, he was aware of the motion of celestial bodies, constructing sundials on the walls of his family home that visitors would use to tell the time. In 1661 he entered Trinity College, Cambridge. A fervent mathematician and philosopher, he began to research infinity, God and geometry and it was in these early writings the word 'gravity' first appeared.

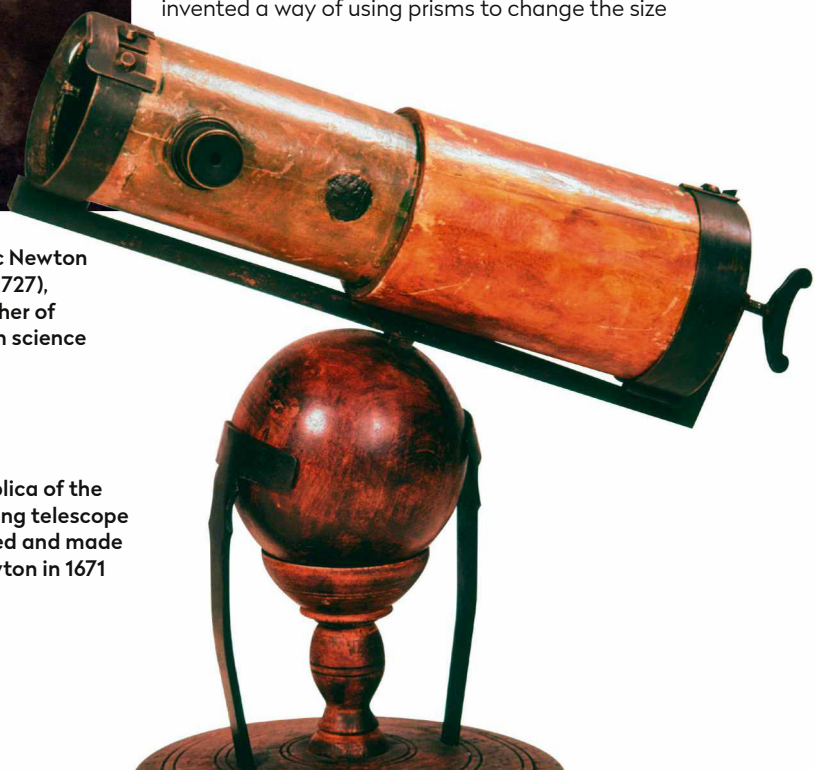
Newton returned to Woolsthorpe in 1664, when the plague closed Cambridge. During this period of isolation, he developed a new form of mathematics that underpins almost all of mathematics and physics today: calculus. Fellow mathematician Gottfried Wilhelm Leibniz also developed the technique independently, leading to a lifelong feud over the method's true inventor.

At Woolsthorpe, an enduring myth also formed: that Newton, sitting in the garden, was struck on the head by an apple causing him to 'discover' the universal force of gravity. Newton never referenced this tale, though he reportedly said watching one fall was a source of inspiration. It is clear from his notes, however, that it was during this time that Newton became aware of the pull of gravitational attraction.

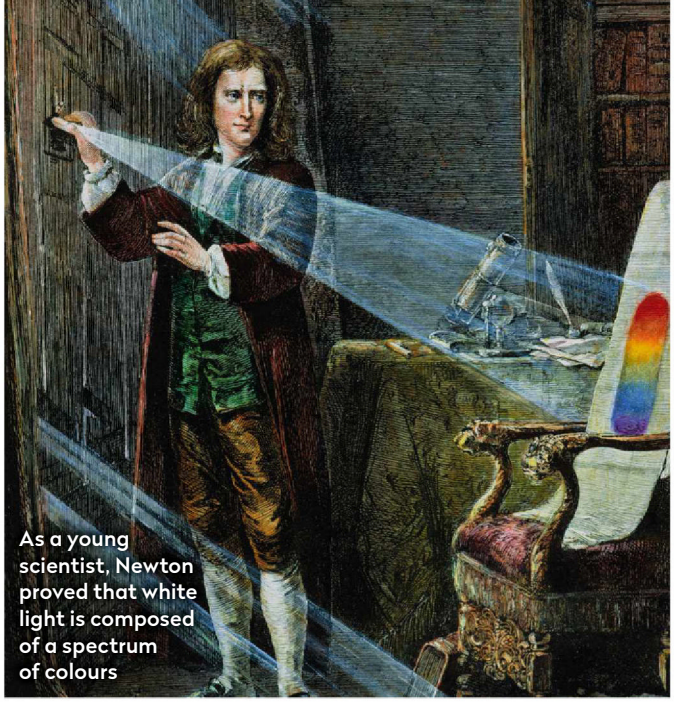
Lighting the way

Newton's thirst for knowledge was unquenchable, and his next target was optics. He carried out experiments that showed that different colours of light were bent at different angles by a prism, and invented a way of using prisms to change the size

▲ **Isaac Newton (1643–1727), the father of modern science**



► **A replica of the reflecting telescope invented and made by Newton in 1671**



As a young scientist, Newton proved that white light is composed of a spectrum of colours

Halley's Comet, observed by Newton in 1680, confirmed the universality of his law of gravity

of a beam of light, a technique now adopted in many lasers.

By now, he had realised that most standard telescopes based on spherical lenses produced blurred images, and believed that he could do better. He began to make his own lenses in a makeshift laboratory outside his dormitory.

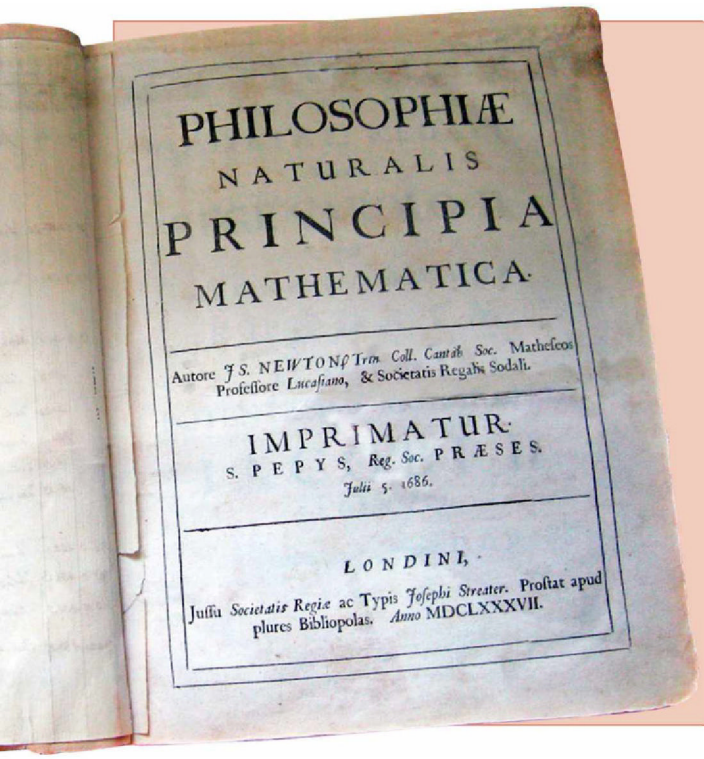
Newton soon understood that the problem was not the lenses, but instead the nature of white light. He discovered that white light was composed of a rainbow, dispelling the longstanding misconception that white was a single colour. Armed with this knowledge, he built a new 'reflection' telescope, using mirrors to focus light instead of lenses. His device, just 16cm in length, was equal in magnifying power to the best European telescopes of the day.

He returned to Cambridge, where he was made Lucasian Professor of Mathematics in 1669. After this, Newton was made Fellow of the Royal Society, but his secretive and difficult temperament led to his isolation from the academic community. This changed in 1681, when he began making observations of the movements of a new comet that had appeared in the sky. His insights attracted the attention of Edmond Halley, after whom the comet is now named.

Through correspondence with Halley, Newton began to compile his research into a logical form. This resulted in his master work: *Philosophiæ Naturalis Principia Mathematica*. Published in 1687 and funded by Halley, *Principia* formed the basis of classical mechanics, the theory of how large bodies move under gravity. Most famously, the work outlined Newton's three laws of motion.

Newton moved to London in 1696, where he took up the position of Warden and then Master of the Royal Mint, responsible for England's coinage. He became President of the Royal Society in 1703, just before he published his seminal book, *Opticks*, on the theory of light and colour. He was knighted by Queen Anne in 1705 and died in his sleep in London on 31 March 1727. He was the first scientist to be buried in Westminster Abbey.

Anita Chandran is a PhD student from Imperial College London



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA

Autore J.S. NEWTONO Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Juſſu Societatis Regiæ ac Typis Joſephi Streater. Proſtat apud plures Bibliopolas. Anno MDCLXXXVII.

The three laws

Newton's contributions to physics are wide-reaching, but his three laws of motion are among his most important work

Newton began working on his laws of motion in his notebook, entitled *The Waste Book*, during his isolation at his family's farm in Woolsthorpe. His three laws came to fruition over many years and were finally presented in *Philosophiæ Naturalis Principia Mathematica* in 1687. They can be summarised as:

▶ A still object will remain still, or a moving object will continue to move, unless a force acts upon it. To make an object move or stop, you need to apply a force to it.

▶ The greater the force applied on an object, the greater its acceleration; the greater the mass of an object, the larger the force required to move it. This force is measured in Newtons, where one Newton is the force needed to accelerate 1kg to 1m/s.

▶ Every action has an equal and opposite reaction. Forces are always found in pairs: if you apply a force to an object, the object will apply an equal and opposite force back.

◂ **Perhaps the greatest work in the history of science, Newton's *Principia* laid down the principles of planetary motion, dynamics and gravity**

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

How to observe lunar occultations

Make accurate records of stars and planets as they disappear behind the Moon

You can time the moment that stars or planets like Mars are hidden by the Moon

With the drama of Mars disappearing behind the Moon last month, interest in occultations – when one Solar System body moves in front of a more distant astronomical object – is at a high. Most commonly occultations involve stars or a planet, but they can be, for example, an asteroid occulting a star. The common factor is that light from the distant object is blocked for a short time as the occulting body passes in front of it. As the Moon orbits Earth, it hides stars and planets, and these are known as lunar occultations. The Moon moves within five degrees either side of the ecliptic and so doesn't occult the same objects all the time.

Occultations are time- and place-dependent, so not everyone will be able to see the same occultation, and those who can will see it at slightly different times. Lunar occultations have given observers the chance to discover double and multiple stars. First-magnitude Antares, for example, hides its fifth-magnitude companion Antares B in its glare, but during a lunar occultation when the main star is hidden behind the Moon, the companion star becomes briefly visible.

During an occultation the star's light will 'go out' instantly as if someone had just switched it off.

PETE LAWRENCE, MEL JEFFERY X 6

Mell Jeffery is the occultation section director at the Society for Popular Astronomy (SPA)

If the star being occulted happens to be close to the north or south poles of the Moon, then a 'grazing occultation' occurs, where the star disappears and reappears behind lunar features seen in profile on the Moon's edge or limb.

Occultations are best observed when they take place at the dark, unlit, limb of the Moon. Disappearance is easier to observe, as you can watch the Moon and star get ever closer. To document your observation and send the information to an astronomical society or scientific body, record your location, equipment, the occulted star and time of the event, as well as anything unexpected you observed.

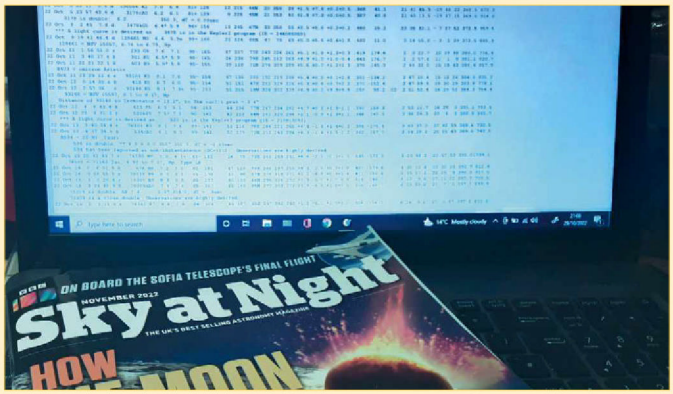
Along with a telescope, to record an event you can use a stopwatch and an accurate clock with a seconds readout. You won't be able to watch the occultation and keep an eye on what the real time is, so keep your eye on the sky. As soon as the occultation happens, start the stopwatch. Later, at a suitable moment, look at your clock and stop the stopwatch, noting that time down. Deducting the stopwatch time from the clock's time will tell you the exact time that the occultation began.

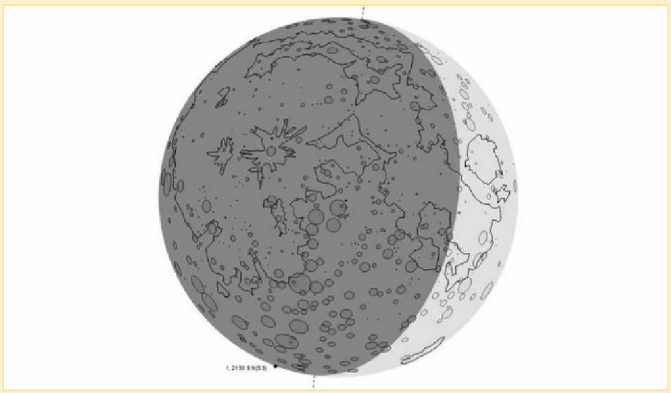
They are easy and satisfying to observe, especially for novice observers, and it is something that can be done on those nights when the Moon's light takes deep-sky targets off the menu. So, check out *BBC Sky at Night Magazine*'s Highlights pages each month for details of any bright events and have a go!

What you'll need

- Software for predicting lunar occultations, available from the International Occultation Timing Association (IOTA), **occultations.org**
- Publications that give lunar occultation predictions of brighter objects but not location-specific timings. For example, *BBC Sky at Night Magazine* or those from national astronomy societies
- A stopwatch to record the time of an event
- An accurate clock with a seconds readout
- A telescope; a useful size is a 4-inch refractor or larger, depending on the brightness of the object being occulted
- A template for recording your observations or an astronomy observation notebook

Step by step





Step 1

Download lunar occultation prediction software such as Occult v4. Input your location details and a date range to get a list of occultations specific to your location. Astronomy publications and local and national astronomical societies can also help.

Step 2

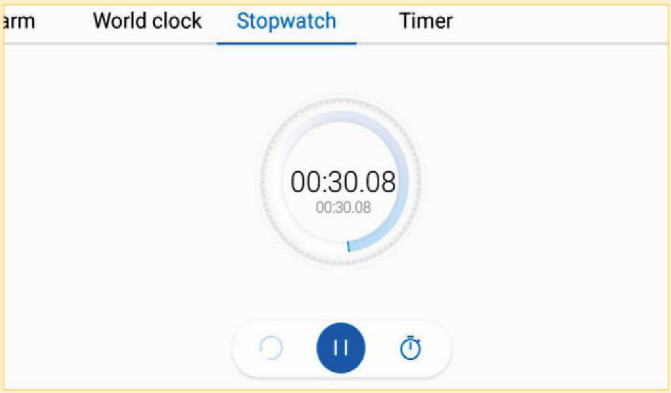
Choose which lunar occultations to observe. Determine where on the lunar limb the star will make its disappearance and reappearance. Disappearances on the dark limb are easier to gauge, as you watch the star as the Moon moves ever closer.

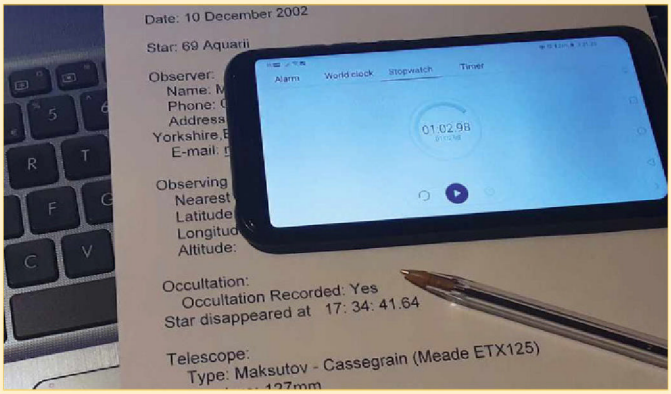
Step 3

Check the location you are observing from and make sure you can see the Moon at the time of the event. Set up your equipment. Make sure you are familiar with moving it steadily (if it is not motorised) and practice using your stopwatch.

Step 4

Observe the occultation. Make sure you watch the star as it moves towards the Moon during a disappearance, or that you are observing the area of the lunar limb where the star should make its reappearance, as the limb itself won't be visible if it's in shadow.





Step 5

Start your stopwatch as soon as you see the star disappear. Then, looking at an accurate clock, stop the stopwatch, noting the precise time. Deduct the stopwatch time to pinpoint the start of the event at your location. This also works for the reappearance.

Step 6

Record the details of the event either for yourself or to send to the relevant bodies, such as IOTA, if required. As the software predicts an event time, you may find that there is a difference to the time that you observed the occultation.

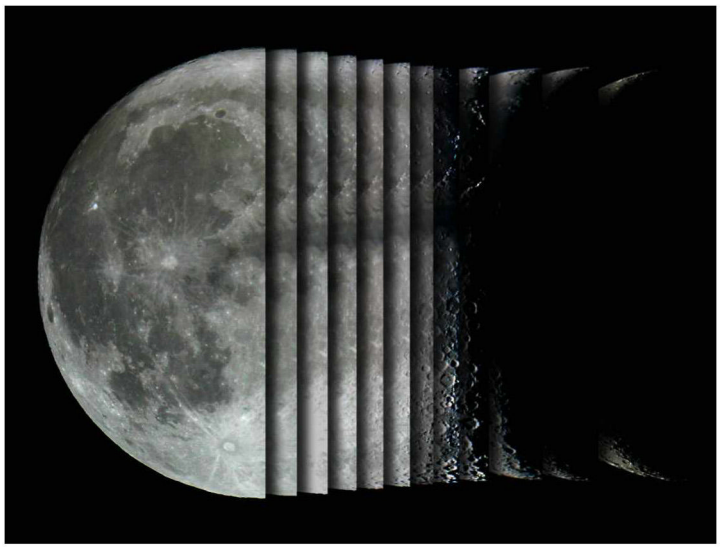
Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

A growing and shrinking Moon

Photograph the journey from perigee and apogee to build a striking composite

The full Moon on 6 January occurs 34 hours and 11 minutes from lunar apogee, the point in the Moon's orbit when it is furthest from Earth. The opposite position is lunar perigee, when the Moon is closest to Earth. Having an elliptical orbit around the Earth–Moon centre of mass (barycentre) means the Moon passes through apogee and perigee once every lunar month.



▲ **A finished composite dramatically showcasing how the Moon's apparent diameter varies throughout a lunar month**

Apogee and perigee aren't that big a deal astronomically, but when full Moon occurs close to one of these positions, it does present a good opportunity to catch the full Moon when it appears largest (at perigee) or smallest (at apogee) in our sky.

The distance between the Moon and Earth is constantly varying and so the Moon's apparent size constantly varies too. There are small variations caused by the position of the Moon in the sky. When rising or setting, for example, it is one-Earth-radius further away than if it were directly overhead. This isn't what we want to capture. We're interested in the changes in apparent size caused by the Moon's physically changing orbital distance from Earth.

A game of patience

Taking an image of the full Moon at apogee gives you a good starting point for a year-long project. By taking images of the full Moon every month, using the same optical setup, it will be possible to place them side by side to compare their apparent sizes. An apogee full Moon will appear smallest, the subsequent full Moons slowly growing in size until the full phase synchronises with perigee, as will be the case in August this year. If you have the stamina, following the full Moons past perigee and back to apogee once again will show how their apparent diameters shrink once again.

If you don't have the patience, time or confidence to attempt a year-long project, there is a 'quick-fix' option. Choose a period when the weather looks clear and settled and photograph the Moon every day as it passes through its phase cycle. The weather makes this a real challenge, but while losing one or two days may be less than ideal, the principle will still work. By recording the Moon using the same optical setup every day, combined with a bit of graphic creativity, you can place your shots side by side to show how the Moon's apparent diameter changes throughout the month. It is a great project to try, and relatively easy to put into practice.

In our step-by-step guide opposite we give you the basics for photographing the Moon at a sufficient scale to show its apparent size variability. In addition, we suggest a method of graphically presenting your results to maximum effect. As we head into the winter and spring, the fuller and then early waxing phases will be best-presented. If you don't fancy getting up early to catch the trickier waning phases, there should be enough coverage to show at least half an orbit's variability.

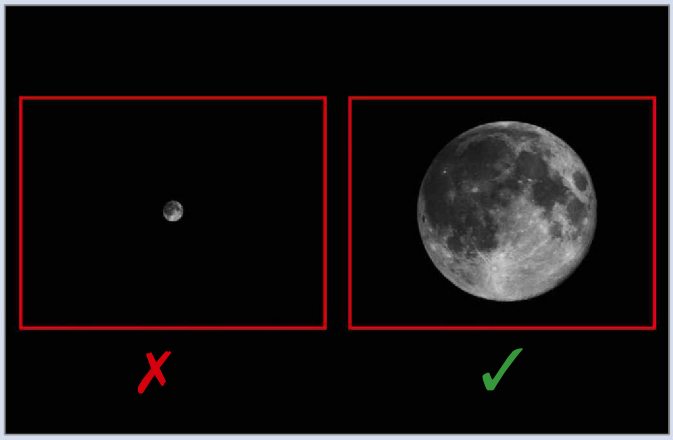
Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

Equipment: A DLSR camera or equivalent, attached to a telescope

✉ **Send your images to:**
gallery@skyatnightmagazine.com

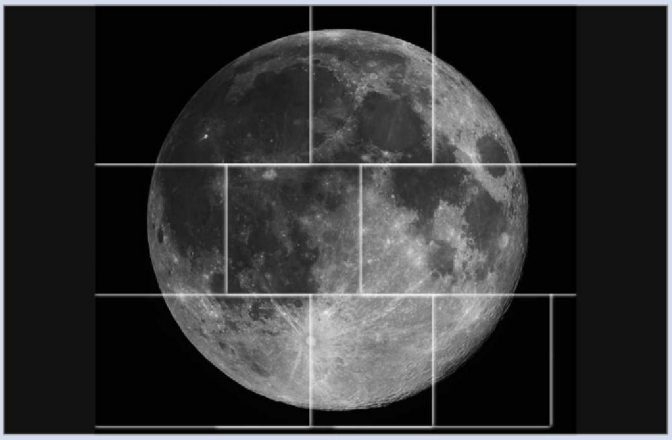
ALL PICTURES: PETE LAWRENCE

Step by step



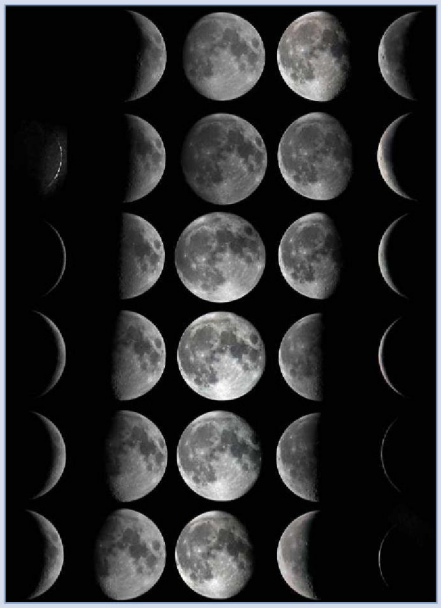
STEP 1

Image scale is important for this project. If you go too small, any size variation will be hard to see. A focal length around 1,000mm and a DSLR or equivalent should allow you to capture the entire lunar disc at sufficient scale to show the variation. Typically this can be achieved by connecting your camera to a telescope.



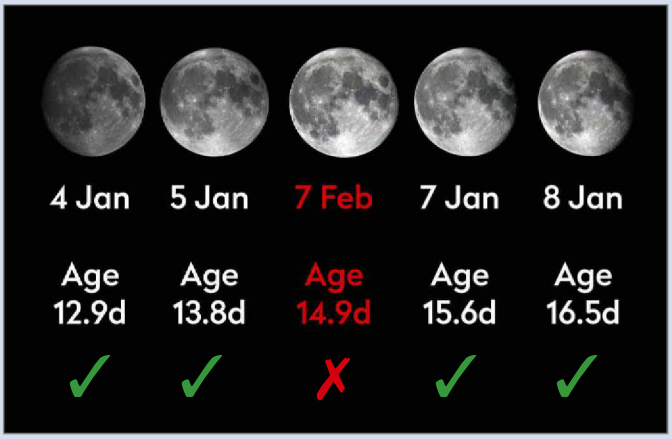
STEP 2

A high-frame-rate setup at higher image scale for mosaic capture will work too, albeit with a lot more work. Here you'll need to capture the Moon in overlapping sections. We recommend nine panes or fewer. Once captured, process each pane and combine using your preferred graphic-editing software to create a full disc.



STEP 3

It is important that every capture is made using the same equipment and image scale. Attempting to grab a capture every day throughout a lunar month is a tall order and, unless you are very lucky, unlikely to be achieved. A few days missing here and there are not a major problem, but the more you capture, the better the end result.

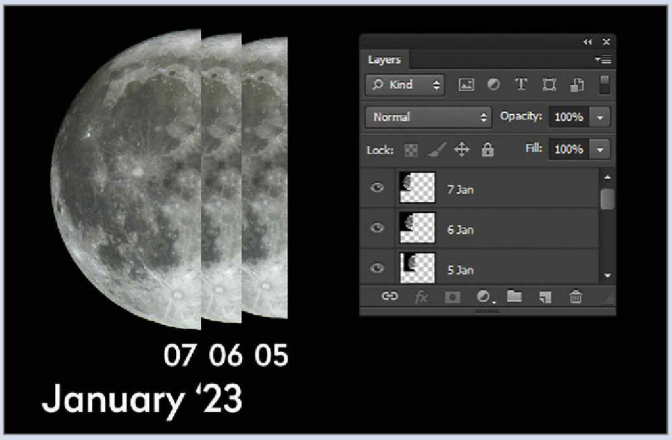


STEP 4

Note that lunar months are not equivalent. You can't take a photo of a 1, 2, 3 and 5-day old Moon in month one and complete the sequence with a 4-day old Moon from the subsequent month, as it won't show the correct apparent size. Sequences need to be consecutive in time in order to work.

STEP 5

Once you have grabbed a sequence, it's time to assemble them to show how the size changes. Your images should be to the same image scale, which means they can be directly laid next to one another to show how the Moon's diameter changes over time. A scale next to the composite will help amplify this fact.



STEP 6

Alternatively, show the changes in size by cutting each image in half and combining them in a way that compares the cut edge lengths. Another method is to cut a same-width-diameter strip out of each image and align them side by side to show the diameter changes. Ensure each strip has a date label attached.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Deal with uneven backgrounds and bloated stars

Using Georg Hennig's GIMP plug-ins to refine your astrophotos

▲ Charlotte's start image of the Monkey Head and Jellyfish Nebulae, alongside the final corrected image. 'Background Gradient' and 'Rounds Stars' from Georg Hennig's suite of astronomy plug-ins removed vignetting, flattened the background and refined the stars

The GNU Image Manipulation Program (GIMP) is free image-processing software that can be used to process astronomy images. Its layout, adjustment and filter capabilities are very similar to Adobe Photoshop and it can be a good alternative for newcomers to astrophotography.

Plug-ins are an excellent way to automate, simplify and speed up some of the complex image adjustments astrophotographers often need to make, such as star removal, colour (or 'chroma') control and data stretching.

While Photoshop and PixInsight have some well-known examples, GIMP also has a few options that have been around for over a decade. We take a look at a couple of Georg Hennig's from his 'Astronomy' suite of plug-ins.

To begin, if you don't already have it, you can download GIMP at **www.gimp.org**. It is free, open source and cross-platform. To download Georg Hennig's plug-ins, visit **hennigbuam.de/georg/gimp.html** and navigate to the appropriate compressed file for your version of GIMP. In our case, this was the Windows version. Locate the compressed file (usually in the 'Downloads' folder), right-click on it and select 'Extract All'. Move the released files to C:\Program Files\GIMP2\lib\gimp\2.0\plug-ins. You will then find all 12 plug-ins by clicking through Filter › Astronomy in GIMP.

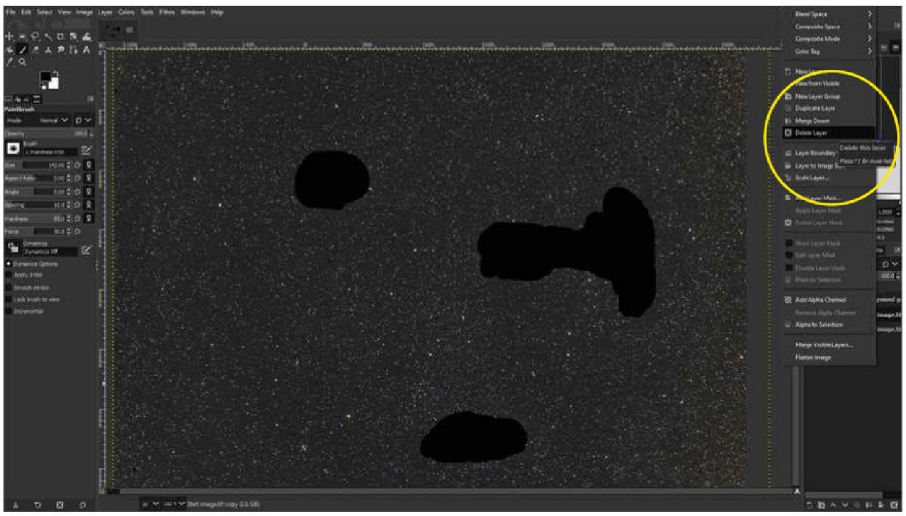
A portion of the plug-ins are used for stacking and calibrating astrophotos, which today is more commonly performed with designated stacking software such as DeepSkyStacker or Sequator. A couple have a more artistic purpose. For example, one will draw a border around your image and will allow you to annotate it with key information.

Problem areas

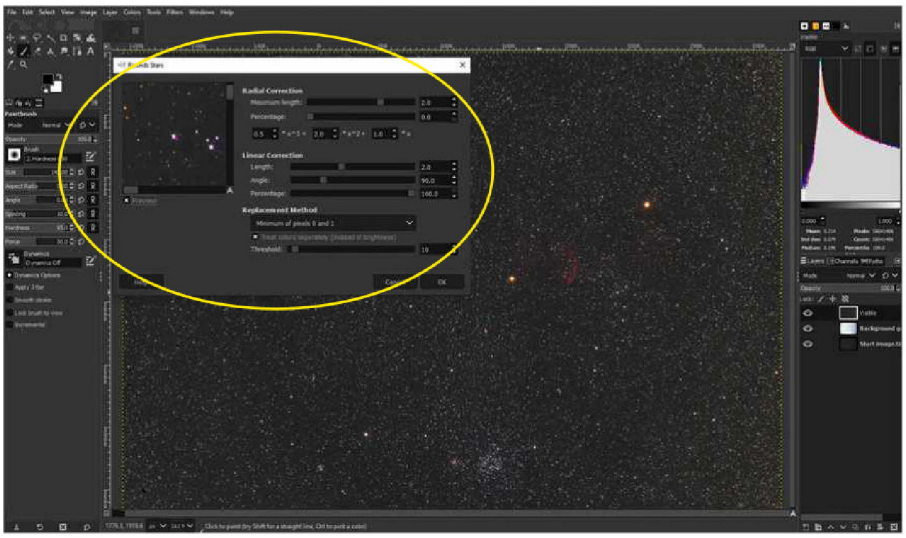
The two plug-ins we will focus on are the 'Background Gradient' and 'Rounds Stars' functions, to first flatten an uneven background and then control bloated or trailing stars. We applied these to our image of the Monkey Head and Jellyfish Nebulae (the start image, above), which had already been stacked in DeepSkyStacker. While the main background appeared even, there was some vignetting in the corners which created a noticeable gradient. This was where 'Background Gradient' came in, as we could create a gradient map that could be subtracted from our image to remove the vignette.

Before we applied this, however, we had to hide all the bright objects in the image

▲ **Screenshot 1: On a new layer, paint over all areas that contain objects brighter than the background. Use the 'Background Gradient' filter to flatten the uneven background**



▲ **Screenshot 2: Once this step has reduced any vignetting and flattened the background, delete the masked layer to reveal the nebulae again. It's then time to tackle the stars**



▲ **Screenshot 3: Experiment with the settings in the 'Rounds Stars' preview menu, depending on how much correction your stars require for bloating and trailing**

(except for the stars); in this case, the nebulae and star cluster. Hennig's instructions propose cutting out the objects before applying 'Background Gradient'. However, he also highlights that results are inconsistent and depend heavily on the size of the nebulae or galaxy in the field of view. We suggest the following method, which requires some trial and error to get right, but achieves consistent results.

First, right-click on the base layer and select 'New from Visible'. This creates an identical layer above (see right-hand side of Screenshot 1). Click the paintbrush icon on the left-hand side and ensure the colour is set to black or grey (highlighted). A menu will pop up that allows the size of the brush to be altered by clicking and dragging the anchor point. Paint over the brightest areas in the image, trying to ensure that only the bright areas are covered. This removes bright patches that the plug-in will (incorrectly) map and so provides a dark field for the correction.

Vignette vanquished

You can now apply 'Background Gradient' (click Filters › Astronomy). A menu will pop up that allows you to select the size of the area to sample, to flatten the background. However, leave the default values. Click 'OK' and let the program run. The resulting background has a reduced vignette and flatter background (see screenshot 2). Right-click on the layer you added and select 'Delete this layer' to reveal the nebulae again.

Now to reduce the appearance of the background stars that currently overwhelm the image and detract from the main target. Apply 'Rounds Stars' to control these (click Filters › Astronomy). The menu allows you to determine the extent to which the stars need correcting (highlighted, screenshot 3). Click and drag options in the preview window to assess whether the corrections are appropriate.

The final image (see opposite) has a flatter background and more refined star field, ready for any further processing, such as applying GIMP's Levels, Brightness, Contrast and Colour functions.

3 QUICK TIPS

1. For gradient removal, make your paintbrush as small as possible to cover bright areas with precision.

2. If your gradient removal is too severe, use the opacity slider to reduce the effect on your image.

3. After applying 'Rounds Stars', use a black layer mask to paint through any bright stars you'd like to keep .

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

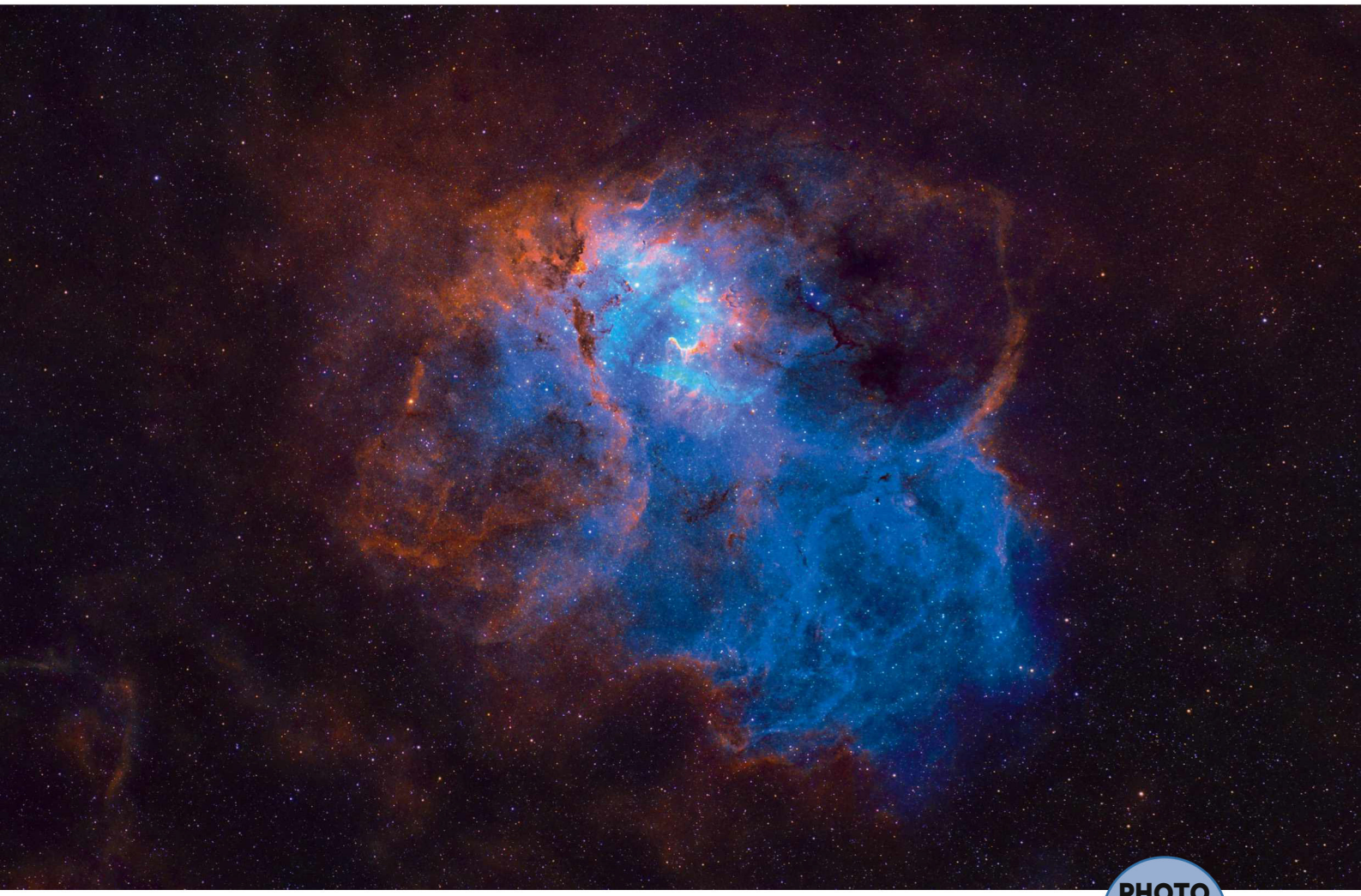


PHOTO OF THE MONTH

△ The Lion Nebula

Daniel Hightower, Hardeeville, South Carolina, USA, 15–20 October 2022

Daniel says: "I've always loved Ha regions that are filled with lots of OIII. It makes for such a dramatic image. The intense ionising gas in the Lion Nebula, including a pair of Wolf–Rayet stars, is just too exciting not to try and go deep with narrowband data. I went for 130–150 frames each at 300 seconds of Ha, OIII and SII, which got me more than 34 hours of data."

Equipment: ZWO ASI6200MM Pro camera, Takahashi FSQ-106EDX4 refractor, Planewave L-350 mount
Exposure: 34.6h total
Software: SG Pro, PixInsight

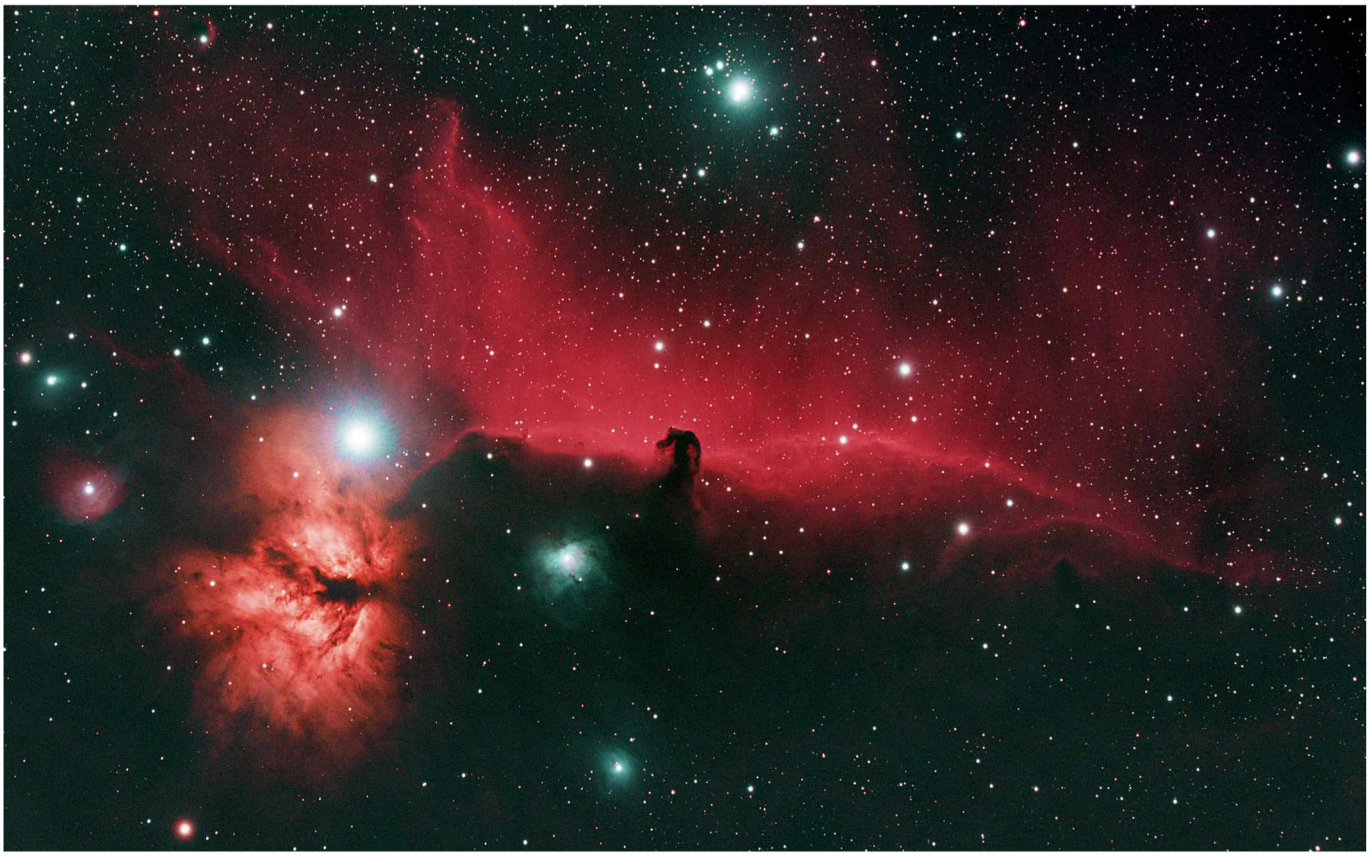
Daniel's top tips: "Narrowband imaging produces some beautiful palettes and the false colour combinations are numerous. Traditional palette representations are great, but don't be afraid to do your own thing. I enjoy the golds that come out of a SHO palette that isn't overly green or yellow. It creates a nice contrast to the blue OIII regions. I suggest processing your star data separately so you don't get weird star colours or hyper-saturated stars while trying to get the most out of the nebula. Be creative, try new things and don't be afraid to mix it up with different colour combinations!"

Maximum totality ▷

Michael Shapiro, Farmington Hills, Michigan, USA, 8 August 2022

Michael says: "Getting a great total lunar eclipse image has long been a goal. I woke up early and went out to a nearby field where I set up my Celestron scope and computer. I was rewarded with an excellent view towards the western horizon and a clear view of totality."

Equipment: ZWO ASI294MC Pro camera, Celestron NexStar Evolution 8-inch Schmidt-Cassegrain **Exposure:** 1′ 30″, 70ms **Software:** FireCapture, AutoStakkert!, Photoshop



△ The Flame and Horsehead Nebulae

Claire Bradshaw, Horsham, West Sussex, 5 February 2022

Claire says: "These are among my favourite targets and I've tried many times to get a good image. I bought a new camera in December 2021 and set out to capture as much data as possible in February this year. I'm very happy with the result. This is a reprocess of the data, using new techniques and processes that I've learned during the year."

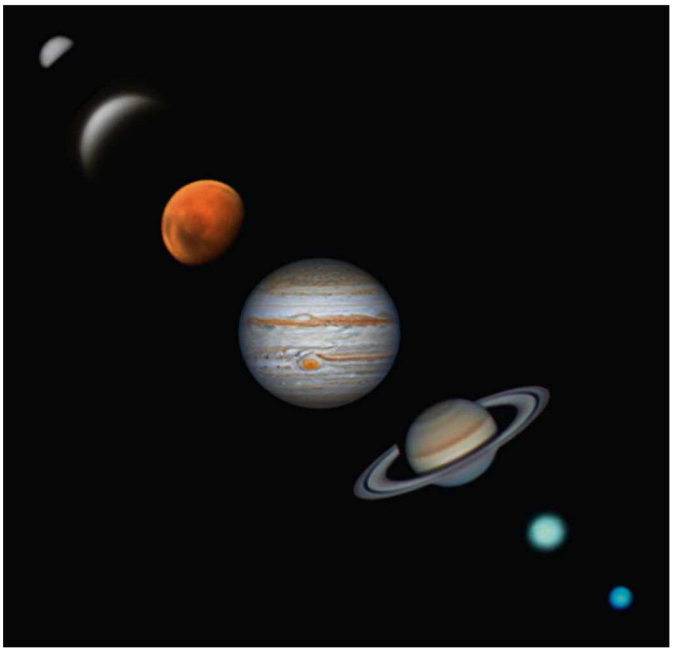
Equipment: Altair Astro 26C camera, Altair Astro Starwave 102ED-R refractor, Sky-Watcher HEQ5 Pro mount **Exposure:** 7h **Software:** NINA, APP, Photoshop

The Skull and Crossbones Nebula, NGC 2467 ▷

Sean Liang, remotely via El Sauce Observatory, Chile, February 2021 to November 2022

Sean says: "The archival data was acquired from Telescope Live, which is a global online telescope network that allows hobbyists like me to do remote astronomy and obtain previously acquired data."

Equipment: FLI ProLine PL9000 camera, PlaneWave CDK24 astrograph, Mathis MI-1000/1250 mount
Exposure: 13h
Software: PixInsight, Photoshop



△ Family portrait

Ivana Peranic, Brighton, 2021–2022

Ivana says: "I took up astronomy in 2020, and two years and a few telescopes later I've finally managed to catch all the planets with my Celestron CPC800. All the photos were taken from Brighton except for Mercury, for which I had to go to the South Downs early in October to get it clear of the horizon. It's been a great challenge!"

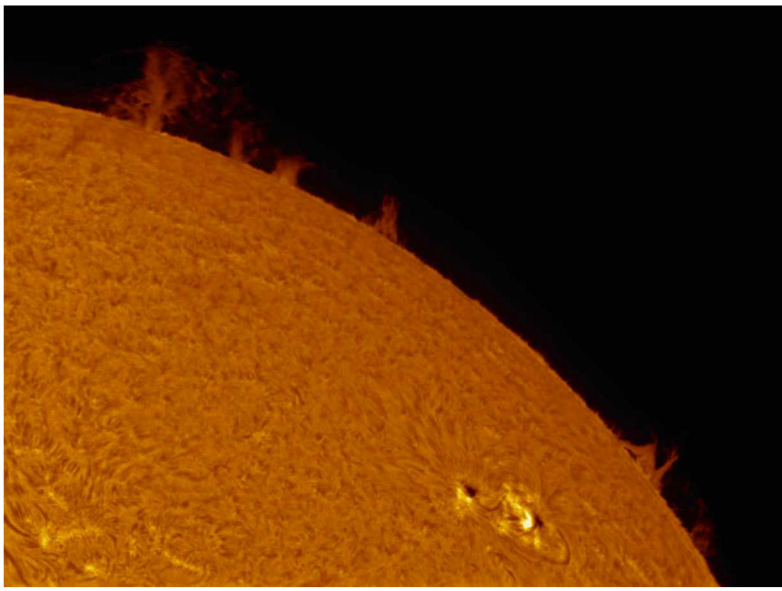
Equipment: ZWO ASI224MC camera, Celestron CPC 800 GPS XLT 8-inch Schmidt-Cassegrain **Exposure:** range from 1.42ms to 973ms
Software: SharpCap, AutoStakkert!, RegiStax, GIMP

▽ Solar prominences

Hayley Smith, Buckinghamshire, 17 October 2022

Hayley says: "I love to photograph the Sun. Its dramatic and ever-changing nature means that it's always an interesting target. For this image I decided to try to capture the faint prominences along with the active region that can be seen in the lower right. I took separate exposures for the surface and the limb, and then combined the images in post-processing."

Equipment: ZWO ASI174MM camera, Sky-Watcher Evostar 80ED refractor, Astronomik L1 filter, Sky-Watcher SolarQuest mount
Exposure: surface: 500 frames, 28fps; limb: 500 frames, 12fps, best 25% stacked **Software:** AutoStakkert!, RegiStax, ImPPG, Photoshop



◁ The Moon by smartphone

Daniel Ruy Pereira, Oldham, Manchester, 8 October 2022

Daniel says: "This was my first attempt at photographing the Moon with my smartphone. I used my Sky-Watcher 130P Heritage, a tabletop Dobsonian, on my daughter's plastic red table! Using an adaptor, I mounted the phone onto my Plössl 26mm eyepiece and took a one-minute video of the full disc moving across the field of view. I stacked the frames with PIPP and AutoStakkert! before finishing with GIMP."

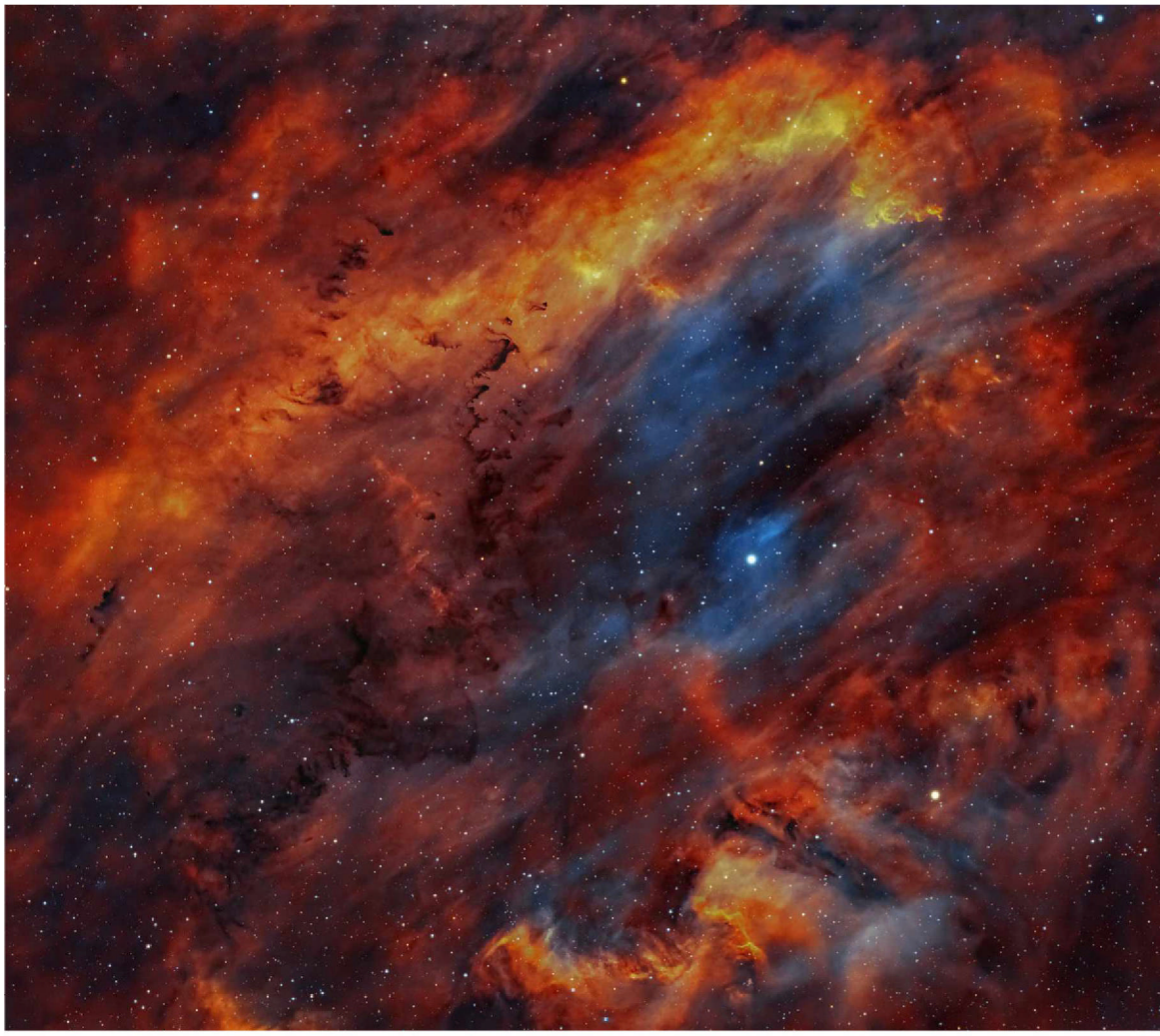
Equipment: Samsung Galaxy Note Ultra 20 smartphone, Sky-Watcher Heritage 130P Dobsonian **Exposure:** ISO 200 f/1.8, 1/10" **Software:** ProCam X Lite, PIPP, AutoStakkert!, GIMP

The Clamshell Nebula ▷

Emil Andronic, Hemel Hempstead, Hertfordshire, 10 September to 16 October 2022

Emil says: "This is a target that's not often photographed, probably because of its proximity to its photogenic neighbours, the North America and Pelican Nebulae, just two degrees to the east. The OIII is quite weak in the area, which is why I only shot 600-second exposures. I'm pretty pleased with the result and I hope more people will look into this beautiful target."

Equipment: QHY294M Pro camera, TS65 f/6.5 quadruplet astrograph, Sky-Watcher EQ6 mount **Exposure:** 23h, 25' total **Software:** APP, PixInsight, Photoshop



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Outstanding
★★★★★
Very good
★★★★½
Good
★★★½☆
Average
★★½☆☆
Poor/avoid
★½☆☆☆

PLUS: our roundup of the latest cool astro gadgets, gifts and gear, Brain Cox's new book on black holes, and more

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Vaonis Vespera Observation Station

An all-in-one scope-plus-camera package that makes astro imaging child's play

WORDS: JAMIE CARTER

VITAL STATS

- **Price** £2,499
- **Optics** Apochromatic quadruplet refractor
- **Focal length** 200mm, f/4
- **Sensor** Sony Exmor IMX462 CMOS
- **Mount** Motorised single arm, altaz, Go-To
- **Power:** 7,000mAh lithium-ion rechargeable battery
- **Tripod** Tabletop aluminium, fixed height
- **Ports** Proprietary USB-C for charging, Wi-Fi
- **App control** Singularity
- **Weight** 5kg
- **Supplier** Vaonis
- **Tel** +33 4 84 98 00 21
- **www.vaonis.com**

Vaonis calls it an observation station, but that's selling this diminutive smart telescope a little short. Vespera is nothing short of an all-in-one astrophotography starter pack for urban observers.

At its core this computerised Go-To device is a telescope, albeit one without an eyepiece to look through. A 2-inch (50mm) aperture refractor, its built-in optics offer 33x magnification and a 1.6° x 0.9° field of view. All that might make it sound like a beginner's telescope, but Vespera is anything but. In place of an eyepiece there's an on-board computer and a Wi-Fi connection. With Vaonis's Singularity app downloaded to a smartphone or tablet, it is possible to see and save whatever Vespera is pointed at.

Vespera is a telescope, but it is also a camera. Inside is an image sensor that takes image after image (roughly every five or 10 seconds) during observation sessions to produce ever-better, clear images. This technique, called image stacking, will be familiar to anyone who has tried deep-sky astrophotography using telescopes, cameras and planetary imagers. Here the entire workflow is automated and delivered in real time, with camera settings for thousands of deep-sky objects determined by an algorithm. All the user needs to do is choose from Singularity's database of recommended targets, customised to a location via a smartphone's GPS, and keep an eye on the progress of the image.

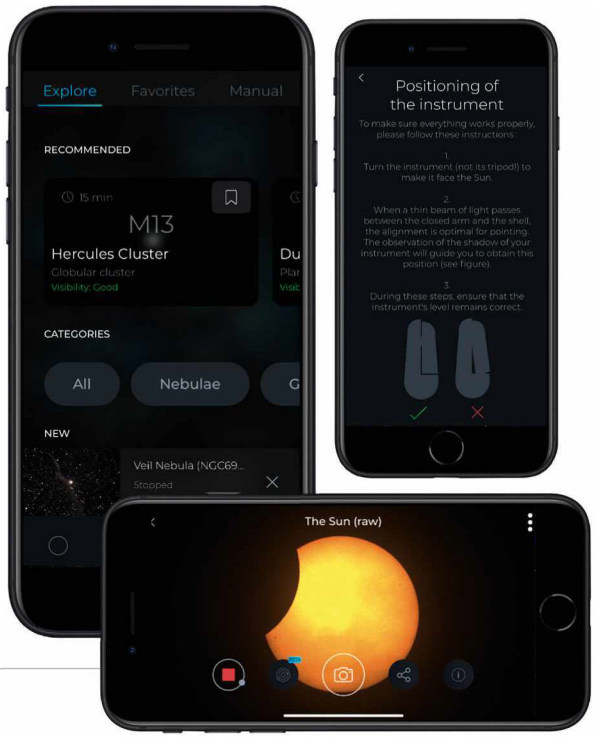
Self-stacking simplicity

Some bright objects require just a few images before they look more or less at their best. For example, the famous globular cluster in Hercules, M13, required only a couple of minutes of images before it looked bright and detailed. That's not the same for faint nebulae, which can take up to an hour of repeated ▸

Singularity app

Vespera is operated almost entirely through the Singularity smartphone app (Android and iOS) which presents a list of recommended objects to observe based on your location, slews to an object and quickly begins imaging it. You can see it live-stack and at any time watch a small flick-book-style video of how the composite image has improved. The real joy is in downloading the image to your smartphone's camera roll or sharing it directly to social media. The entire operation is automated, but you can manually control the image parameters and input the coordinates of a passing comet or anything else not in its database.

The Solar Pointing mode, only for use with the optional Vaonis solar filter (£79), enabled us to image the partial solar eclipse on 25 October 2022. Vespera found the Sun within three minutes and perfectly tracked it during a four-hour observing session. Sunspots were easily seen and it was a spectacular experience watching on the app as the Moon gradually obscured part of the Sun's disc.



©THESHED/PHOTOSTUDIO X 3

SCALE

Optics

Vespera Observation Station features a 2-inch (50mm) aperture apochromatic quadruplet refractor telescope with a focal length of 200mm. It has a 1.6° x 0.9° field of view and provides 33x magnification. Its lens is surrounded by a plastic 'dummy' filter that can be popped off and replaced by various optional filters offered by Vaonis.

Tripod and motorised mount

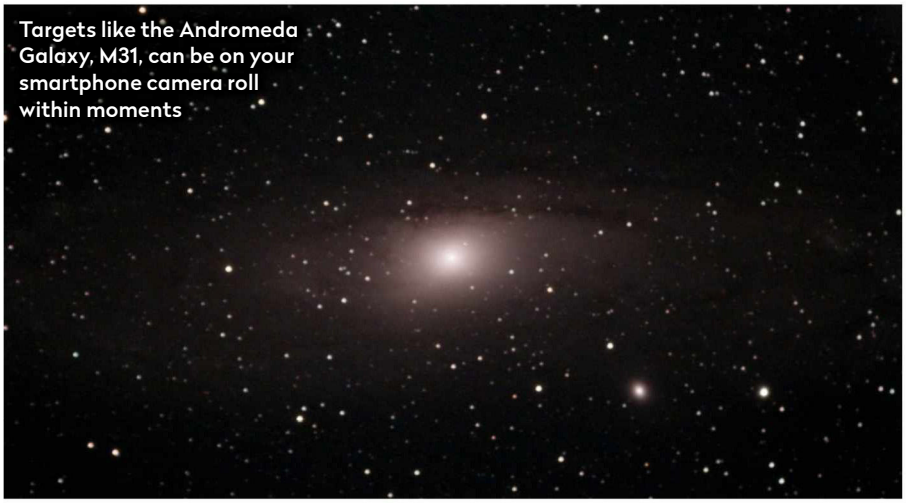
Vespera swivels on a motorised altazimuth mount just above a connector for its very short tabletop tripod. Measuring just 20cm long, the three legs can be disassembled for easy transport, though it is worth upgrading to a full-size tripod. Vespera's undercarriage has a standard 3/8-inch connector that will fit on all photographic tripods.

On-board computer

Vespera captures images using a 1/2.8-inch Sony IMX462 sensor. The on-board 1.6GHz computer uses live image stacking to create images, which it saves to its 10GB flash memory as lossless raw TIFF and FITS files. These can be extracted via Wi-Fi using a web browser on a computer.

Wi-Fi network

Vespera produces its own Wi-Fi network that up to five smartphones or tablets can connect to simultaneously (iOS or Android). Each device must have the free Singularity app downloaded to see, save and share Vespera's latest images, though in our tests the Wi-Fi network stretched only around five metres.



Targets like the Andromeda Galaxy, M31, can be on your smartphone camera roll within moments

▲ **Bright detail in the Dumbbell Nebula, M27. Vespera's algorithm automatically selects the camera settings**

Proprietary charging cable

To recharge Vespera's 7,000mAh battery – which is quoted to last four hours but in practice lasts at least six – you use a USB-C cable. It has a proprietary connector at one end, so care is needed not to lose it, but it's magnetic so once attached won't easily fall out.

▸ imaging before detail, structure and colour reach their maximum. At any stage of the process a composite image of the frames taken so far can be saved to a smartphone or tablet camera roll, or easily shared to social media. There is no branding on the images whatsoever, with finished JPEGs saved in their native 1,920 x 1,080-pixel resolution. That's about two megapixels, technically making Vespera the lowest-resolution 'smart' telescope around.

Vespera has a few tricks up its sleeve for anyone wondering if it is only good enough to be considered an astrophotography novelty. For starters, it is possible to export and share images as RAW image files. Advanced users can also engage full manual mode and bypass the default image parameters for deep-sky imaging. There is also a new mosaic mode that allows it to take multiple separate images of objects that don't fit in its field of view – such as the full extent of the Andromeda Galaxy, M31 – and automatically stitch them together. The feature wasn't available to review at the time of testing, but is expected to be live at the time of publication.

Using Vespera is child's play. As well as its excellent Singularity app, it comes equipped with star pattern recognition software that takes just a few minutes to align using plate-solving. Unlike other smart telescopes, it has auto-focus, though the images it produces do lack a little sharpness. Vespera cannot take images of planets. Nor does it produce fabulous lunar images; even a bright full Moon looked rather dull in finished images. It can be used for solar observing, if you pair it with Vaonis's specialist solar filter. But what Vespera excels at is battling light pollution. With its optional light pollution filter in place – and even without it – it is possible to get exquisitely bright and surprisingly colourful images of the kind of deep-sky objects that are impossible to see with the eye from light-polluted locations.

Although it performs even better under dark skies, where its limiting magnitude is 13, Vespera is an ideal option for urban astronomers frustrated by their lack of access to galaxies, nebulae and star clusters, with pockets deep enough to pay its premium price.

VERDICT

Build & design	★★★★★
Ease of use	★★★★★
Features	★★★★☆
Go-To/tracking accuracy	★★★★★
Imaging quality	★★★★☆
OVERALL	★★★★☆

KIT TO ADD

1. Solar, light pollution and dual-band (nebulae) filters

2. Custom-made Vespera backpack

3. Portable smartphone battery

FIRST LIGHT

Sky-Watcher Quattro 150P f/4 astrograph

This more-than-capable imaging specialist gets full marks for observation too

WORDS: TIM JARDINE

VITAL STATS

- **Price** £499
- **Optics** Newtonian reflector, 0.86x aplanatic coma corrector
- **Aperture** 150mm
- **Focal Length** 600mm, f/4; 515mm with coma corrector
- **Focuser** 2-inch Linear Power Crayford-style focuser
- **Extras** Dovetail bar, tube rings, 6mm x 30mm finder scope
- **Weight** 5.7kg
- **Supplier** Optical Vision Ltd
- **Email** info@opticalvision.co.uk
- **www.** opticalvision.co.uk

Having enjoyed using Sky-Watcher's Quattro telescopes in the past, we were intrigued by the latest model to join the family, the comparatively diminutive Quattro 150P. As the name suggests, it is an f/4 telescope with a 150mm primary mirror. It includes a corrector that takes the telescope down to a speedy f/3.45.

Quattro telescopes are designed to be used as astrographs, that is, paired with a camera; so the 150P doesn't come with eyepieces. However, optics that make a good astrograph also produce good visuals, and with Jupiter nearing opposition we tried the Quattro with a couple of our own eyepieces, using the supplied 2-inch extension tube. Our 4.5mm lens gave a pleasing 133x magnification and the views of Jupiter were really quite remarkable: sharp, detailed and colourful. Encouraged by the results, we switched to a 13mm, 100° eyepiece for a widefield view at 46x, which gave us a mouth-watering look at the Double Cluster in Perseus. Without the coma corrector, stars near the edge of the field of view were affected by the inherent coma that you expect with an f/4 instrument, but the Quattro demonstrated that despite its astrograph pedigree, it can offer worthy visual observations if desired.

With our CCD camera attached to the corrector, the Quattro 150P really came into its own. Focusing was easy and accurate, and the star shapes in the corners of our 16mm sensor images were perfectly acceptable. The Quattro has thin spider vanes, producing sharp diffraction spikes, so the Pleiades cluster, M45, proved to be an ideal target and we were able to capture plenty of nebulosity with three-minute exposures.

Versatile performer

The wide view on offer is great for large targets like the Andromeda Galaxy, M31, or the nearby Triangulum Galaxy, M33, and in both cases we were impressed by the fast capture of plenty of good-quality data. We even managed to capture a cheeky shot of October's partial solar eclipse, using a white-light filter.

This astro imaging specialist, then, delivers enjoyable visual use on planets, deep-sky ▸

f/4 parabolic mirror

Sky-Watcher has a deserved reputation for producing affordable, good-quality telescope mirrors, and the parabolic 150mm f/4 primary mirror in the Quattro 150P maintains that standard. It has multiple silicon dioxide coatings to provide protection from the elements.

In conjunction with the coma corrector, the optics suck in photons at a rapid f/3.45, which makes the Quattro especially attractive to astrophotographers limited by the weather. Fast focal ratios make for shorter exposures, perhaps through a DSLR, which connects directly to the field flattener with a T-ring. Even better, a CMOS camera would really maximise the available clear-sky time, allowing for a greater number of exposures. To make the most of the f/4 optics we found it preferable to check the mirror collimation before each session, while the steel tube construction and open back design allowed the mirror to be cooled and ready to go after an hour or so.

©THESHED/PHOTOSTUDIO X 2, CELESTRON X 2

Vixen-style dovetail bar and tube rings

A Vixen-style 45mm dovetail bar is supplied, along with sturdy Sky-Watcher tube rings. These are easily adjusted by hand to allow for telescope balancing and positioning, and the top of the rings have threaded holes to fit additional accessories such as a guidescope.

2-inch dual-speed (1:10) Crayford-style focuser

Quattro telescopes have Linear Power Crayford-style focusers that use ball bearings to support the drawtube. We found the focuser precise and accurate in use and very smooth, particularly when fine-focusing. It easily supported our chunky eyepieces and camera equipment. Locking the focuser in place didn't shift the image or focus point.

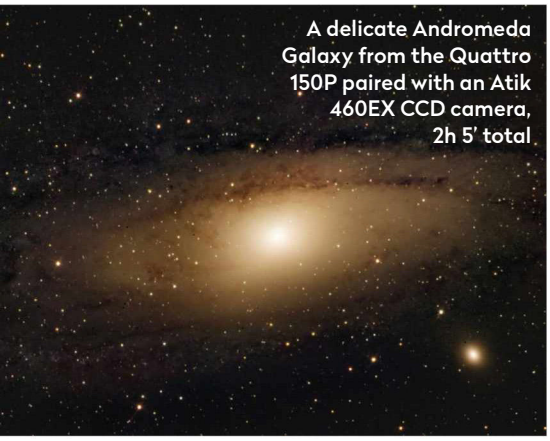
6mm x 30mm finderscope

A standard finderscope shoe is fitted to the tube near the focuser and a straight-through 6mm x 30mm finder with a wide field of view is supplied to help with star alignment. The finderscope has crosshairs for accuracy and is easily adjusted to line up with the Quattro's optics via two thumbscrews.

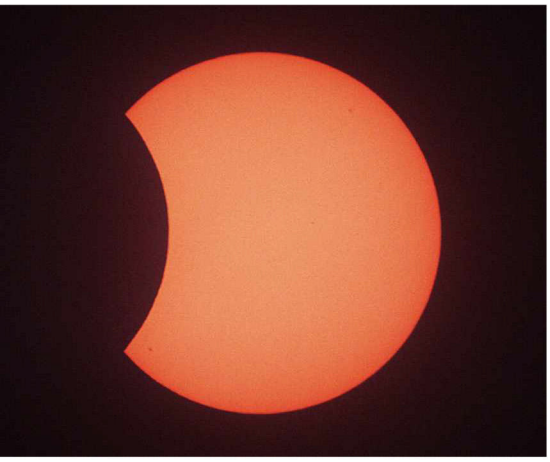
M48 2-inch aplanatic super coma corrector

An essential part of the optical system for astrophotography, the corrector includes an ED element in its four lenses and produces a flat image circle of 21.7mm, enough for APS-C-sized camera sensors. Cameras are attached via an M48 thread; a back focus distance of 55mm is optimal for best results.

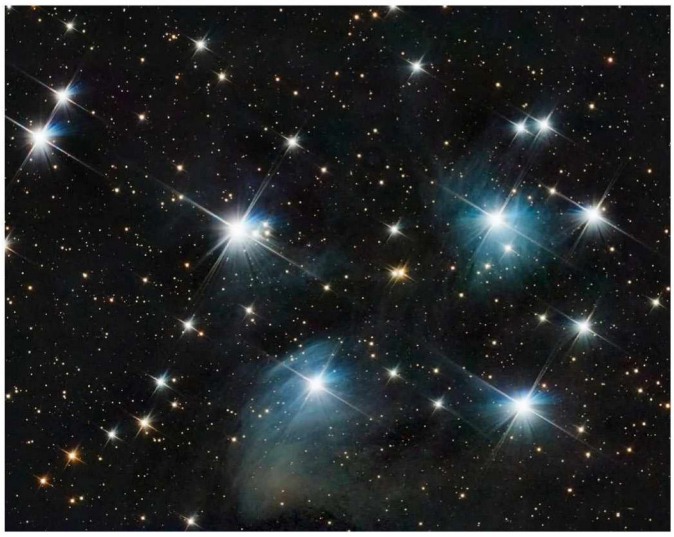
FIRST LIGHT



A delicate Andromeda Galaxy from the Quattro 150P paired with an Atik 460EX CCD camera, 2h 5' total



▲ Partial solar eclipse on 25 October 2022, single exposure through Baader solar film



◄ Fine detail and nebulosity in the Pleiades, M45, again with the Atik 460EX CCD and a total integration time of 2h 35'

Light, compact design

At only 5.7kg and less than 60cm (2ft) in length, the Quattro is easily manageable and suitable for a wide range of mounts. Unlike the larger models, there are no baffles in the 150P, which keeps the weight down. With a DSLR camera fitted, the balance point is near-central.

▸ objects, and even a lucky solar image when the chance came, proving to be quite the all-rounder. It was at this point that we realised how much we love the Quattro 150P. It reminds us of our previous good experiences with our own larger version: compact and easy to use, fast, and capable of great results in the shortest time.

It was also at this point, however, that we remembered the foibles of f/4 telescopes, particularly when it comes to collimating. The optics are a lot less forgiving of slight errors, and unfortunately our review model arrived with several issues in the way it had been set up. For instance, the centre ring on the primary mirror was incorrectly placed and the secondary mirror was attached to its mount at a wonky angle, while the alignment of the spider vanes pulled the secondary mirror off to one side, producing diverging diffraction spikes. These issues, although easily remedied by experienced users, would make the Quattro 150P we used a frustrating telescope if you were new to fast Newtonian reflectors or precise collimation techniques. This has impacted the build and design score we were able to give it.

Fortunately, we had advanced collimation equipment available and were able to reasonably align the mirrors despite the errors in the factory setup, but if this was our own telescope we would strip it down and accurately rebuild it, blackening the shiny bevelled edges of the mirrors, as it has all the makings of an excellent performer once correctly set up. It really is a tempting purchase, especially at just £499. For such a capable 6-inch, fast astrograph with field flattener, the asking price seems a complete bargain, and well worth an afternoon tweaking and tuning the instrument until it performs at its true potential.

VERDICT

Build & design	★★★½☆
Ease of use	★★★★½
Features	★★★★½
Imaging quality	★★★★½
Optics	★★★★½
OVERALL	★★★★½

KIT TO ADD

1. Canon or Nikon M48 x 0.75 adaptor ring

2. Sky-Watcher EQM-35 Pro Synscan mount and tripod

3. Sky-Watcher 17Ah power tank

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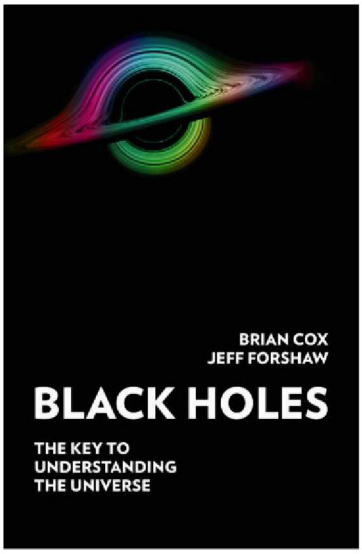
New astronomy and space titles reviewed

BOOKS



Black Holes: The Key to Understanding the Universe

Brian Cox and Jeff Forshaw
Harper Collins
£25 ● HB

Black holes are some of the most intriguing and awe-inspiring objects in our Universe. Where else do space and time flip roles and the end of time waits for you, no matter what you do? There are many popular science books about black holes available to the curious reader, but there are few like this. *Black Holes* is not your average light bedtime reading, and you'll need your full concentration to follow all the Penrose diagrams. But fear not: although this is a heavy book, conjuring many memories of head-scratching in general relativity lectures, the authors do a very good job of guiding the reader.

The book starts with the basics of spacetime, giving you the tools you'll need to navigate your way using this new coordinate system. Penrose diagrams feature heavily, and you will understand how to read them to interpret what would happen to you should you stray close to or happen to 'fall into' a black hole, as well as what happens in a wormhole. There is very little maths in the book, and the authors tell the story at a nice steady pace that engages the reader, focusing attention on the subject matter with relatable examples.

The best part of the book is the final chapters, where thermodynamics and quantum information meet to describe the Universe as a hologram. This is one of the best books for describing the basics of holography and how it came about. The authors skilfully and logically lead the reader to what feels like a very natural conclusion. In the final pages you may even begin to ask yourself: are we indeed living in a giant quantum computer? *Black Holes* is essential reading for anyone keen to understand the essence of general relativity without the maths. The book connects the similar challenges we face in building a quantum computer and developing the correct theory of quantum gravity. And so, by the end of the book we come away with an appreciation that there is much more to black holes than we may have originally expected, and that we may well be living in a holographic Universe. ★★★★★

What happens to the material that falls into a black hole? The authors explain the latest thinking

PITRIS/ISTOCK/GETTY IMAGES

***Laura Nuttall** is a Future Leaders Fellow at Portsmouth University*

Interview with the authors

Brian Cox & Jeff Forshaw

How do we know what we know about black holes?

The Event Horizon Telescope collaboration recently captured photos of the supermassive black hole in the centre of our Galaxy and the bigger one in M87. Before EHT, our central black hole was inferred from how it shapes the orbits of nearby stars. Small black holes of a few solar masses have also been detected in binary systems. But what interests us most is more theoretical: none of the observations can probe what happens inside a black hole. We develop our understanding by calculating how the laws of physics play out. This is not as speculative as it sounds: a lot of ideas fit logically together in a single, compelling framework. It's led to the idea of emergent space, and to the related idea that the world is a hologram.

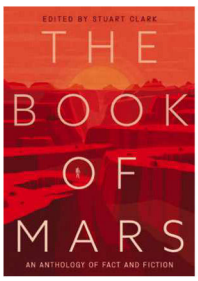
What's left to be discovered?

We're only just getting to grips with the quantum physics of black holes and the nature of the black hole interior. One exciting prospect is to try to 'build space' in Earth laboratories using quantum entanglement. The way space appears to be built has similarities to the way quantum engineers are trying to build quantum computers – the robustness of space seems related to an idea called quantum error correction, central to the construction of robust quantum computers. Perhaps finding the theory of quantum gravity is intimately related to one of the big technological challenges of the 21st century: building a quantum computer. We think that's a thrilling possibility.

***Jeff Forshaw** and **Brian Cox** are particle physicists based at the University of Manchester*

The Book of Mars

Edited by Stuart Clark
Head of Zeus
£30 ● HB



Mars has intrigued many creative and eloquent individuals over the years, inspiring them to write captivating stories and document exciting discoveries. In *The Book of Mars*, astronomy writer Stuart Clark brings together 80 written pieces from the past century and a half, combining excerpts of novels and short stories based on Mars by eminent science fiction writers, together with various reports from leading scientists. The book is loosely broken down into six thematic sections and before each piece there is a brief introduction by Clark. These introductions tend to focus on the authors and, while informative, many could have benefitted from additional context by providing, for example, the overall premise of the book that the selected chapters originally came from, or explaining whether the content of scientific texts is still held to be true today (certainly, some of the older scientific texts now seem closer to fiction). Despite this, the range of pieces included, both in genre and age, prove extremely interesting and, at times, positively quirky.

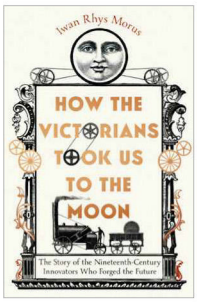
Particularly enjoyable is the variety of short stories featured, from the moving dilemma of Mary Robinette Kowal's *The Lady Astronaut of Mars*, to the oddly amusing reluctant hero in Stephen Bartholomew's *The Hermit of Mars* and the gripping archaeological dig described in Henry Beam Piper's *Omnilingual*.

The Book of Mars demonstrates perfectly how the Red Planet has and continues to fascinate us, making us strive to explore it further. If you're interested in Mars – science or fiction – this book is for you. ★★★★☆

***Penny Wozniakiewicz** is a senior lecturer in space science at the University of Kent*

How the Victorians Took Us to the Moon

Iwan Rhys Morus
Icon Books
£25 ● HB



Iwan Rhys Morus's latest book is a window into an era where innovation and determination combined to reveal a world of possibilities. We're taken on a journey into the forging of scientific societies, the roles that prominent names in physics played in the advancement of Victorian innovation, and the spark of invention that helped shape the future.

The book goes into tremendous detail on the history of the Victorian era and is at times deeply fascinating, although at other points the momentum falters. The central question of how the Victorians took us to the Moon sometimes seems forgotten, and the first few chapters give no indication that the answer will become clear. It is only when we reach the chapters on Fueling the Future and Surveillance that it begins to make sense; what seems like a slow start begins to pick up and recapture our interest.

There are points where the narrative around the elitist and highly male-dominated world of Victorian science can leave an unpleasant taste in the mouth, but at the same time the story gives a deep appreciation for how attitudes within the field of science have changed.

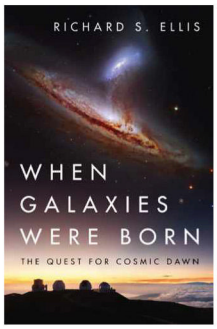
How the Victorians Took Us to the Moon is wonderfully written and draws us in with a historical narrative so detailed that at times it is easy to become lost in fascination. And while astronomy lovers may feel like they need to push through the narrative before the question of lunar exploration is fully addressed, for the more general reader this is a brilliant history of Victorian innovation. ★★★☆☆

***Melissa Brobby** is a communications officer at the UK Space Agency*

When Galaxies Were Born

CUTTING EDGE

Richard S Ellis
Princeton University Press
£25 ● HB



Professor Ellis's long career has taken him from an astronomy undergraduate at University College London in the 1960s full circle to being professor of astrophysics at the same institution today. As a dedicated observational astronomer, he has worked at or overseen many of the world's great telescopes and observatories, from the 200-inch Hale reflector at Mount Palomar in San Diego, California, the Anglo-Australian Telescope at Siding Spring in New South Wales, and the Isaac Newton Telescope in the Canary Islands, to the giant 10-metre Keck telescopes on Hawaii, and many more. In his marvellous new book, he uses his time with these instruments as a backbone to tell the story of his life's work: the search for light from the first stars and galaxies formed in the aftermath of the Big Bang.

Subtitled *The Quest for Cosmic Dawn*, the book is a combination of historical account, autobiography and scientific explication, blended together to take us on a whirlwind tour of the advances made in astronomy since the mid-20th century. These have allowed Ellis and colleagues to identify individual galaxies – and characterise entire populations – at ever-greater distances, taking advantage of the 'cosmic time machine' effect imposed by the limited speed of light to look further back in time. Ellis's explanations of complex scientific and technological challenges faced along the journey are an exemplar of how to bring approachability and clarity to potentially tricky subjects, but it is the fascinating incidental details that really grab the attention. Offering a rare insight into how professional astronomy actually 'gets done', they elevate this to must-read status for anyone interested in the ways of modern science. ★★★★★

***Giles Sparrow** is an author and popular science communicator*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Sunobserver eADC electronic atmospheric dispersion corrector

Price £495 • **Supplier** First Light Optics • **www.firstlightoptics.com**

ADVANCED ADCs greatly improve planetary images, but they need to be recalibrated as the planet's altitude changes. With this electronic device you only need to calibrate once and the rest is taken care of automatically.

2 ZWO ASIAIR mini smart Wi-Fi controller

Price £228 • **Supplier** The Widescreen Centre • **www.widescreen-centre.co.uk**

This box acts as a control hub for your astro-imaging setup, connecting to the free app via Wi-Fi. Half the size of previous models, it's highly portable but still provides multiple power and USB outlets.

3 Space Shuttle charm

Price £21 • **Supplier** The Charm Works • **www.thecharmworks.com**

This sterling silver charm in the shape of NASA's iconic Space Shuttle makes a great gift for a loved one (or for yourself). Measuring 1.4cm long, it can be used as a bracelet charm or a pendant.

4 Stanley unbreakable vacuum flask

Price £70.99 • **Supplier** Stanley • **uk.stanley1913.com**

This heavy-duty 0.7-litre food flask will make sure that your dinner stays safe, even if you're hiking off in search of the darkest skies. The flask can endure all manner of knocks and drops, and keeps food hot for up to 20 hours.

5 Bridgedale merino wool ski socks

Price £25.50 • **Supplier** Go Outdoors • **www.gooutdoors.co.uk**

Making sure your feet don't get too cold is vital if you want to stay out all night observing. These socks are made from merino wool, which helps keep your toes warm, but without too much bulk.

6 Celestron 8-inch dew heater ring

Price £39 • **Supplier** Harrison Telescopes • **www.harrisontelescopes.co.uk**

Keep the dew away permanently with this heater ring. The heater replaces the retaining ring on your Schmitt-Cassegrain telescope, meaning it can be left in place. When connected to an external 12V power source it will warm the telescope, preventing dew.

FROM THE MAKERS OF BBC Sky at Night MAGAZINE

The Astronomer's Yearbook 2023

For an indispensable guide to the astronomical year ahead, don't miss *The Astronomer's Yearbook 2023*. Month by month, our guides and sky charts lead you through the must-see sights. From stars, galaxies and planets to meteor showers, moon transits and comets, we give you the know-how you need to make the most of your equipment and your time under the stars. Whether it's rare conjunctions and occultations or each season's best constellations, you won't miss a thing. Packed with equipment advice, challenges to set yourself, how-tos and astrophotography tips too, this is the expert practical guide you won't want to be without.

Chris Bramley,
Editor, *BBC Sky at Night Magazine*

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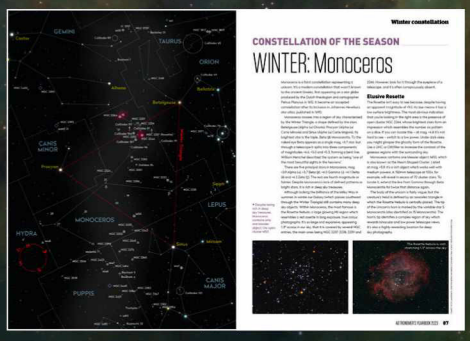
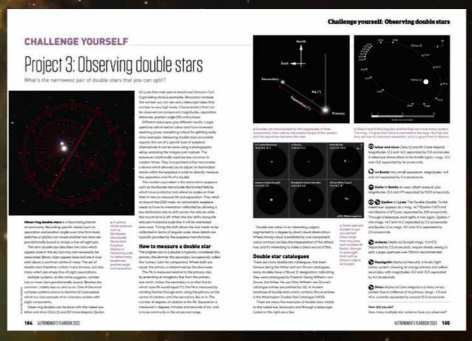
Our month-by-month guides and detailed star charts reveal what to look for and when, from stars and planets to Moon phases and more



Get to know the stand-out constellations of each season, as we highlight their brightest targets and how to best observe them



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TERRY HANCOCK

Melissa Brobby interviews Dimitri Veras

Q&A WITH AN EXOPLANET OBSERVER

Dying stars tend to swallow small, dense planets and tear them to pieces, so how do some planets manage to survive?

How are planets destroyed at the end of a star's life?
In the process of becoming a white dwarf, a star like our Sun undergoes major changes involving its size and luminosity, when the star transforms into a so-called 'giant star'. The star's size increases by a factor of hundreds, and it will easily swallow planets that are too close.
For example, in the Solar System, Mercury and Venus will be swallowed. Some of the planets that are further away will be gravitationally perturbed into a close orbit around the star. We have a few examples of giant planets perturbed in this manner, but still no terrestrial planets. Just after the giant phase, the star shrinks into a small, compact white dwarf.


ILLUSTRATION

▲ **Nearby planets are ripped apart when their star reaches its bloated death throes – but worlds with certain properties have a chance of survival**

How did you go about researching how some worlds survive this process?
Our investigation was one of the first-ever dedicated studies into tidal effects between white dwarfs and rocky planets like Earth and Mars, and asteroids. Tidal forces occur because gravity acts more strongly on one side of a planet than the other. This difference stretches the planet and the stretching becomes more extreme the closer the planet is to the star. Hence, there is a critical distance at which the planet can no longer survive the stretching.

What did your investigation involve?
We created a procedure for computing these tidal effects and provided a type of 'survival guide' for planets with different properties like distance, viscosity and spin. This allows us to determine if a particular planet will survive or be broken apart by the white dwarf, and if so, when. We then used numerical simulations to implement this theory and provide specific examples.

Are small, rocky planets around white dwarfs particularly vulnerable to being torn apart?
The strength of tides is a function of many variables. One of these is the size of the planet, because the gradient of gravitational forces is greater in larger planets, and creates a strong and fast inward gravitational drag towards the star. Hence, smaller planets have a greater chance of surviving because they don't move towards the star as quickly. Another variable that affects tides is how 'hardy' a planet is, which is measured by its internal viscosity. The more viscous a planet is, the longer it can resist the gravitational pull towards the star and to destruction.

What other factors affect a planet's survivability?
One of the most significant is the distance from the white dwarf. Another weaker but non-negligible factor is the spin rate of both planet and star. Planets can be destroyed around many types of stars, not just white dwarfs. Unlike other stars, however, white dwarfs provide a glimpse into the Solar System's future and the future of nearly all known exosystems.

What is the potential fate of the surviving planet when its white dwarf star eventually radiates all its energy and fades?
The radiation of a white dwarf has no direct effect on gravitational tides. However, white dwarfs that have faded are very old, and the timescale over which gravitational tides act is a key determinant of survival. For example, a faded white dwarf that is five billion years old is less likely to host a survivor planet than a faded white dwarf that is three billion years old, simply because in the former case there was more time for gravitational tides to drag the planet in and destroy it.

What do you think astronomers should look out for when hunting and studying exoplanets?
One of the next most significant discoveries will be a terrestrial-like planet orbiting a white dwarf. So far only giant planets and small asteroids have been found orbiting these stars. We've shown that Earth-like planets can survive stably around white dwarfs for long periods. Our results provide a 'guidebook' and an incentive for observers to finally find them, because we've demonstrated that in many cases they can survive for at least hundreds of millions of years.

Dimitri Veras is an associate professor and STFC Ernest Rutherford Fellow at the University of Warwick, specialising in the fate of extrasolar asteroids, comets, moons and planets

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch the year's best sight of Mercury and try to find our pretty targets in Canis Major

When to use this chart

1 Jan at 00:00 AEDT (13:00 UT)
15 Jan at 23:00 AEDT (12:00 UT)
31 Jan at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JANUARY HIGHLIGHTS

Enjoy Mercury's best return to the morning sky for 2023. It can be found just under Sagittarius's teapot, brightening from mag. +1.4 to –0.1 during this time. Gaining altitude quickly, by midmonth it rises around an hour before sunrise. A small telescope shows a 9.3-arcsecond crescent disc shaped like a three-day-old Moon. By 30 January, the disc has shrunk to 6.8 arceseconds, with its phase now gibbous, and it reaches its maximum altitude, rising two hours before the Sun.

STARS AND CONSTELLATIONS

Being summer, the Sun is highest in the daytime sky as it follows its path through the heavens (the ecliptic). The constellations it passes through define the zodiac, although astronomical and astrological borders differ greatly. At night the situation is reversed, with the zodiacal constellations lowest in the sky. Its most northerly location (winter solstice) lies near the border of Taurus and Gemini, halfway between the Hyades and Gemini's twin stars, Castor and Pollux.

THE PLANETS

Venus is low in the early evening twilight, but given its brilliance it is easy to find. As Saturn approaches conjunction it is soon immersed in the twilight glow, passing Venus on 22nd. Mars is transiting around the end of twilight, leaving plenty of time to view. Neptune and Jupiter depart around 23:00 midmonth, followed by Uranus two hours later, then Mars at about 02:00. Later in January, Mercury returns to the morning sky, being observable in the dawn glow.

DEEP-SKY OBJECTS

This month, a trip to Canis Major. Located only 3° southwest of Sirius are the three naked-eye 'Nu' (ν) stars, in a flattened triangle 1° across. The centre one, Nu¹ CMa is an excellent double star with components of mag. +5.8 (yellow) and +7.4 (pale yellow), 17 arcseconds apart.

Here's a pair of open star clusters: NGC 2384 (RA 07h 25.2m, Dec –21° 01) and, 8 arcminutes northwest, NGC 2383. The more conspicuous of the two, NGC 2384 is a compact 5-arcminute hazy oval made up of stars of 8th magnitude and fainter, with a close pair of 9th-magnitude stars on the western edge. NGC 2383 has a triangle of 10th-magnitude stars surrounded by a haze of 11th- to 13th-magnitude stars. The clusters are located in a busy Milky Way star field, complete with a handful of scattered 7th- to 8th-magnitude luminaries. Pretty!

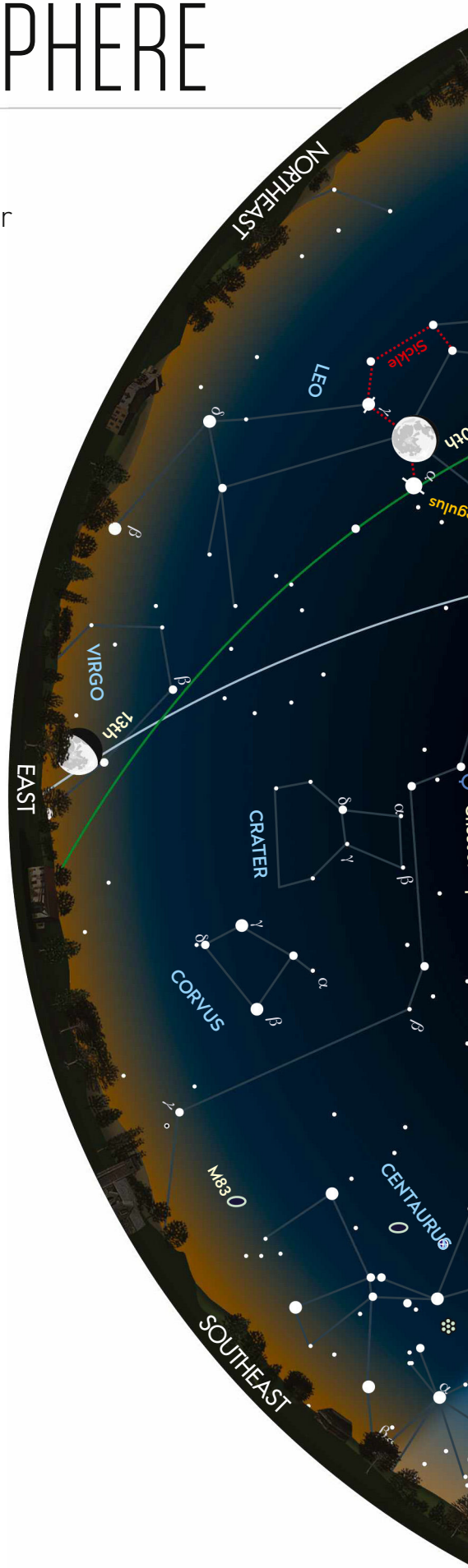
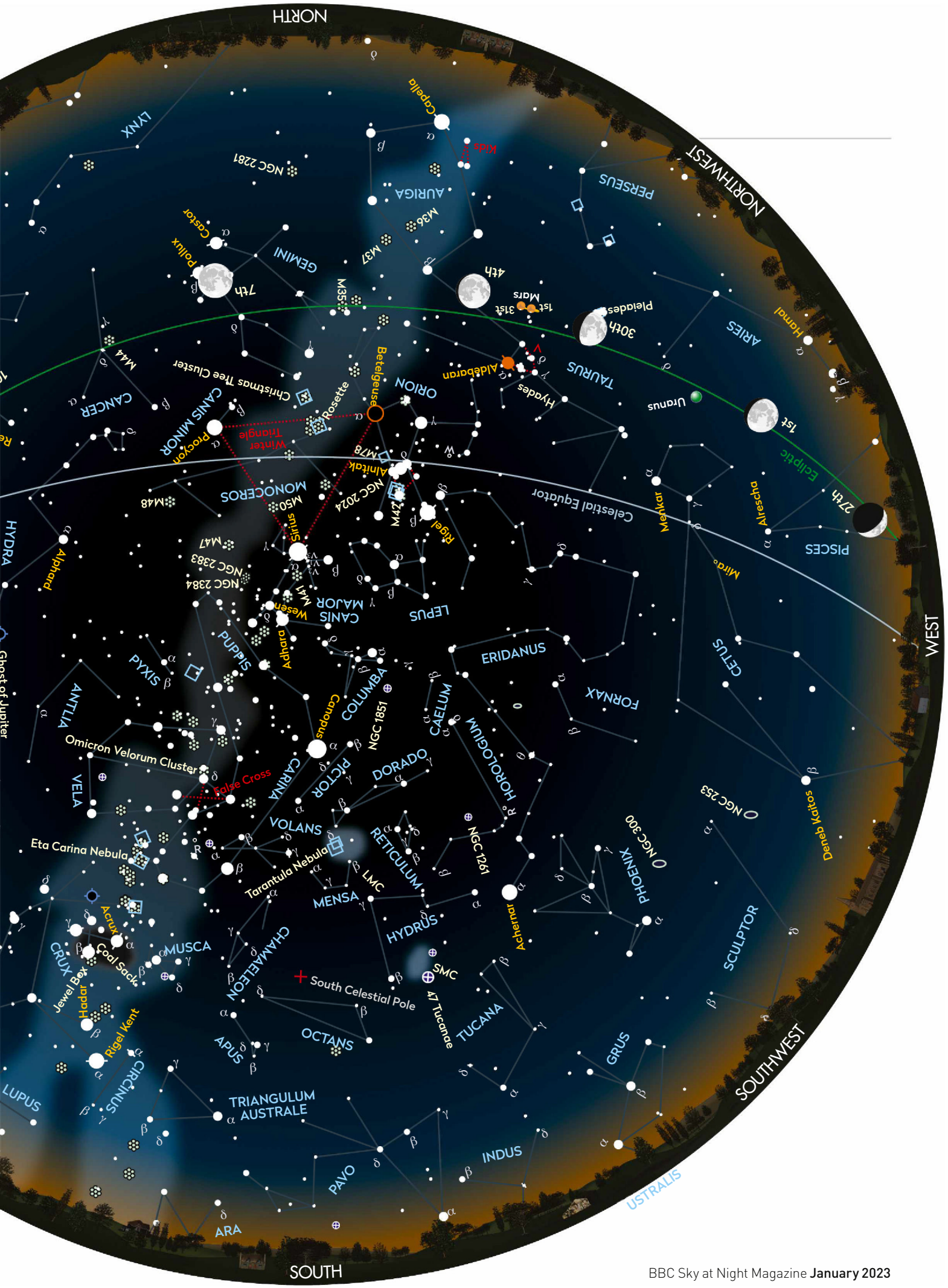


Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
LYNX
NGC 2281
Capella
Kids
AURIGA
M36
M37
M35
PERSEUS
Castor
Pollux
GEMINI
7th
4th
1st
Mars
31st
30th
Pleiades
Hamal
ARIES
M44
CANCER
Christmas Tree Cluster
Betelgeuse
ORION
Aldebaran
Hyades
TAURUS
Uranus
1st
Rosette
CANIS MINOR
Procyon
Winter Triangle
M78
Alnitak
Ecliptic
Celestial Equator
M48
M50
MONOCEROS
NGC 2024
M42
Rigel
Sirius
Menkar
Alrescha
27th
PISCES
HYDRA
Alphard
M47
NGC 2383
NGC 2384
M41
Wezen
CANIS MAJOR
LEPUS
Mirfak
Ghost of Jupiter
PUPPIS
Adhara
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CETUS
ANTLIA
Omicron Velorum Cluster
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NGC 1851
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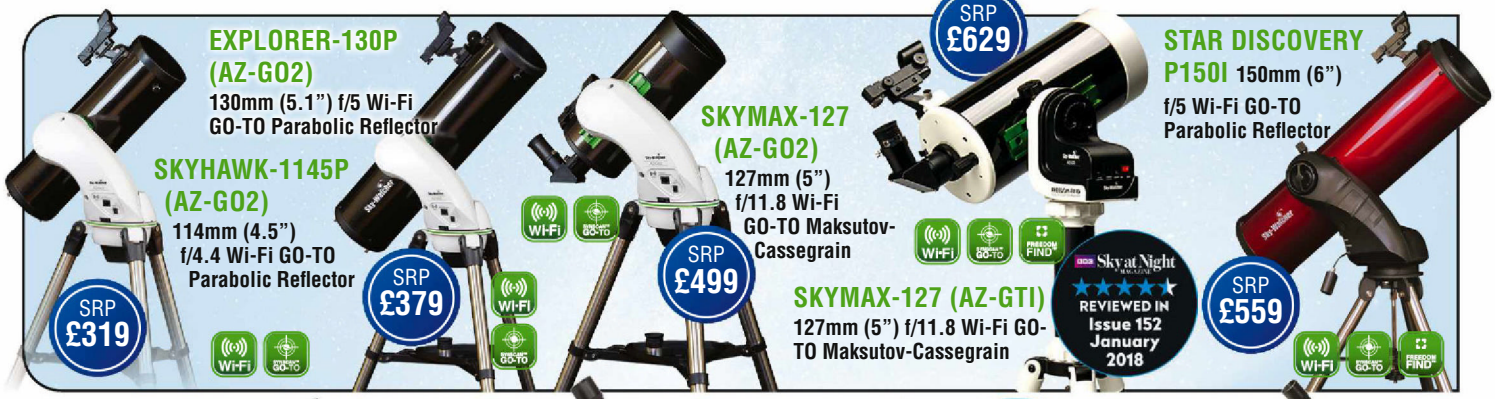

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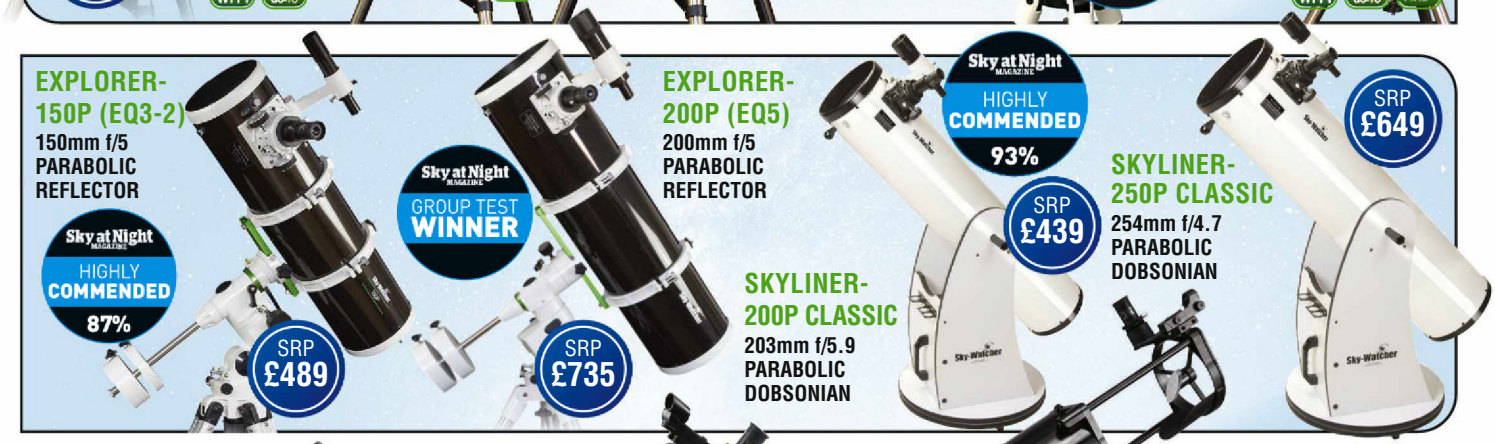

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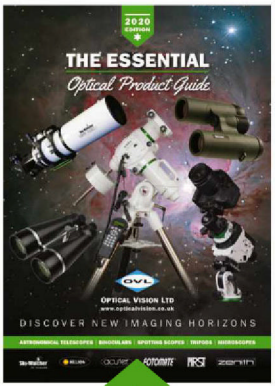

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